THE EPIDEMIOLOGY AND CONTROL OF MALARIA IN PALESTINE

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THIS BOOK IS DEDICATED

TO

LOUIS D. BRANDEIS

AND

BERNARD FLEXNER

PREFACE

The student of history would find interesting material for a thesis in tracing the relation of malaria to the development and prosperity of a country.

Whatever facts of general application research into this important question may yet reveal, there is little doubt that the static condition of Palestine during the last several centuries is due almost entirely to malaria. One has but to pass over the country and see the numerous *khirbet,* or remains of deserted villages, in the vicinity of the marshes to realize the rôle this disease has played in its depopulation. The once famous city of Beth Shan, standing in the midst of an intensively irrigated plain, was in the course of time completely surrounded by water-logged marshes, became one of the most malarious points in a highly malarious area, and dwindled to a small village. The same is true of Jenin—the Ein Ganim of Jewish history. Even the religious zeal and devotion of the German Templars could not withstand the ravages of the disease, and their colonies at Migdal and Semonia had to be abandoned.

If we pass from Galilee and the Valley of Esdraelon to the coastal plain, the effect is even more striking. One sees large stretches of richly watered, potentially cultivable land inhabited only by a few Bedouin tribes, all infected with malaria, and eking out a precarious existence from the proceeds of baskets made of marsh reeds, and from the milk of the buffaloes which wallow in the marshes. The entire hinterland of the famous city of Caesarea is a waste of dunes and marshes, inhabited by about seven hundred souls. One passes a Circassian village half encircled by marshes—one of the outposts colonized by the Turks about forty years ago with hardy stock from Circassia, nine hundred strong. Now there are scarcely fifty souls left in the village, mostly native stock and all stamped with the effects of malaria. This condition is repeated at Ramadan, Jelile, at Nebi Rubin, in short, all along the coast.

Five or six years ago many of the Jewish villages were mournful

spectacles. Almost without exception the Jews had chosen to settle in the most malarial areas. The swampy lands were the least populated and most readily bought; besides they were, on the face of it, the best watered, and water is scarce in Palestine. Probably these were the prime considerations in the minds of the purchasers of the land for the early settlements; of the dangers that lurked in the swamps they were no doubt totally ignorant.

The inevitable happened. Take the settlement of Hulda. It was preserved only by the annual replacement of a population infected with malaria and no longer fully fitted for work. About one-third of the annual budget was consumed by medical aid. During certain periods of the year *more than half* the working force was invalided. Similar conditions existed in Nahlat Yehuda and Ein Genim, in Gan Shmuel and Shuni, in Merhavia, Dagania, and Kinnereth, in short, throughout most of the newer settlements. The older villages were somewhat more resistant, but Athlit, Yessod, and Mishmar were in a hopeless state of disintegration, while Ekron, Hedera, Yabniel, and many others were suffering enormously both from malaria and blackwater fever. The seriousness of the situation was grasped by Mr. Justice Louis D. Brandeis during his visit in 1919, and he was ready to provide the means toward the study of the problem. Such a study was undertaken by the author in 1921 under the auspices of the Hadassah Medical Organization, then the American Zionist Medical Unit.

It seemed best to begin with a modest experiment of malaria control in two or three highly infected sections of the country. These experimental demonstrations were conducted in three localities: Migdal, Kinnereth, and Yabniel. No radical drainage was attempted; in fact, in Kinnereth no drainage was possible, unless one cared to attempt to dry the Jordan. The campaign was carried out along three main lines: (1) detection and treatment of carriers, (2) antimosquito campaign, (3) education.

The first, and perhaps the most important, fruit of this experiment was the change in the attitude of the population toward malaria. Before the first year's work was completed and the results tabulated and analyzed, requests began to come in from other Jewish settlements that we extend our work to them. Even in advance

of the evidence of figures and charts, the attitude of the population had changed; they had come to realize that malaria was a preventable disease.

When the results were tabulated, they carried sufficient conviction to justify the preparation of a country-wide scheme with a proportionately larger budget. Thanks to Mr. Bernard Flexner, the Joint Distribution Committee of America took over the project and provided a two-year budget, which has up to the present been regularly extended, for a complete antimalaria organization, to be attached to the Health Department of Palestine.

This arrangement was effected and the Malaria Research Unit was established in September, 1922. The country was divided first into ten and later fourteen districts centering around the Jewish settlements. In so far as the means permitted, the control was extended to the neighboring Arab villages, with a view slowly to extend the work to cover the entire country. By January 1, 1923, antimalaria work had been organized in all the settlements.

A few figures will illustrate the change which has occurred in the areas under control during the last few years. In 1922, the year before extensive control operations were undertaken, figures compiled in the districts selected for the work showed that each month an average of 5.7 per cent of the population had malaria. In 1923, the average monthly rate had been reduced to 2.9 per cent, by 1924 to 1.1 per cent, and in 1925 to 0.8 per cent.

Large stretches of the land have been freed of their marshes, and work is in progress in others. Hulda, Ekron, Rishon, Nahlat Yehuda, Petah Tikvah, Ein Ganim, and Merhavia are now entirely free from malaria. Most important is the fact that the old indifference is gone. A small outbreak of malaria in a Jewish settlement is the occasion for a storm. Investigations are held and the Unit is blamed (sometimes justly) for not doing the very thing which only five years ago perhaps the same people declared to be impossible.

The attitude in higher quarters also has changed. The colonizing agencies now realize that it is neither good economics nor sound practice to settle people in malarious areas unless provision is made to render these areas habitable. The land, they now realize, has to be rendered fit for colonization. It will not be long, it is hoped, until

they will come to the further wisdom of realizing that the land must be prepared before, and not after, the settlers arrive. The settlers themselves now recognize that it is a foolhardy, quixotic kind of martydom to succumb to malaria, and in two instances they have actually refused to settle in malarious areas unless the necessary preliminary work was done. In other words, malaria has been robbed of its mystic attributes, its inevitability; it has been revealed as a preventable—and often eradicable—disease.

Along with the control work a considerable body of data has been compiled bearing on all phases of the malaria problem. This material forms the subject matter of this monograph. No pretense is made of an analysis of the extensive literature on the subject. Such a survey would require special consideration and would really constitute a study of the history of the development of malaria control in various parts of the world. It was deemed more advisable to limit the subject of this monograph to a rounded presentation of the problem as it presented itself in Palestine and the steps employed in its solution. Most of the data presented are the results of the observations in the laboratory and field by the director, staff, and inspectors of the Malaria Research Unit. Use has also been made, however, of the valuable work of the Malaria Survey Section and of the basic work by Buxton on the classification of the local anopheles.

The greater part of the success of the work of the Malaria Research Unit is due to its field staff. Without the devotion and sympathetic co-operation of the inspectors in the field; without the zeal and enthusiasm of Dr. J. Shapiro, the field medical officer, and Mr. Saliternik, the senior inspector, the work could not have been accomplished. It is a great satisfaction to have occasion to record this fact and to express to all of them my gratitude for their loyal and unstinted labors.

ISRAEL J. KLIGLER

JERUSALEM
January, 1928

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CHAPTER I

TOPOGRAPHY AND CLIMATE

For a clear understanding of the malaria problem of a country it is necessary to have some idea of its topography, climate, and the social and economic conditions which constitute the background of the picture. The configuration of the country, the character of the geologic formations, the volume and distribution of rainfall, the temperature and its seasonal variations—these are the physical factors which determine, to a greater or lesser degree, the distribution, prevalence, and intensity of the disease. Of equal importance are the habits, customs, and economic conditions of the inhabitants. Consequently, we shall endeavor, without entering into details, to give a brief sketch of the topographic, climatic, and social conditions of Palestine that have a particular bearing on the problem of malaria.

Topographically, Palestine falls into four main divisions: (1) the Coastal Plain, a strip of land varying from two to twenty miles in width, and extending from Haifa at the north to Gaza at the south. (2) At Haifa the Coastal Plain turns eastward into a plain extending from the coast of the Mediterranean to the valley of the Jordan. This plain, known as the Valley of Esdraelon, is a strip of land only a few miles in width which cuts the hills transversely. (3) Along the Jordan is the valley of the river extending from the Sea of Galilee at the north, to the Dead Sea at the south. The greater part of this valley is less than a kilometer in width, and lies in a ravine (the Ghor) between the ranges of hills. (4) Between the Coastal Plain and the Jordan Valley lies the range of hills which bisects the country longitudinally into two plains, distinct from each other in climate, vegetation, etc. These hills are chiefly of limestone formation. They rise slowly from the western and northern plains through a chain of foothills to the highlands of Judea, Samaria, and Galilee; they then drop more sharply on the east to the Jordan. Figure 1 is a typical cross-section of the country, show-

ing the general configuration and relative extent of the plains and bisecting hills.

Small though Palestine is, it exhibits a surprising variety of conditions. The Coastal Plain is a highly fertile valley consisting of

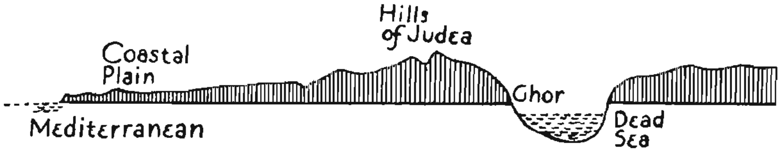


FIG. 1.—Cross-section of Palestine, Lat. 31°4′

Pleistocene sand and gravel and sedimentation from the hills. But there are factors which render large areas of this plain so malarious as to be practically uninhabitable. The coast line is extremely regular, the only natural bay existing in Haifa. Parallel with this regu-

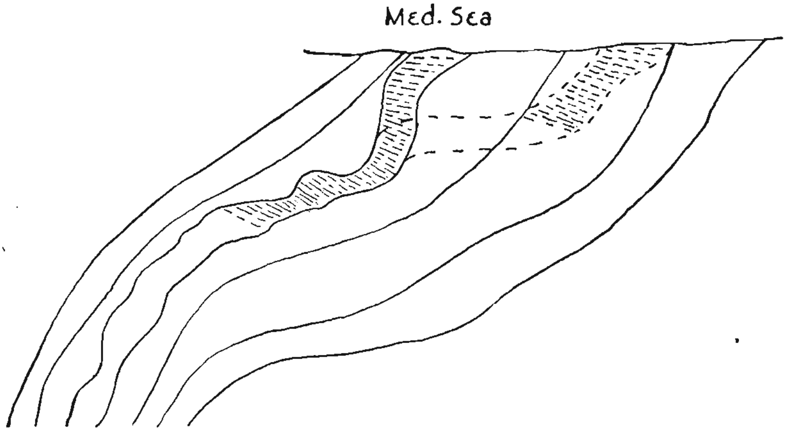


FIG. 2.—Deflection of streams along the coast

lar coast line and only a mile or less inland is a broken chain of sandstone ridges and sand dunes, partially or completely blocking the courses of all the principal streams draining into the Mediterranean and constituting a most serious source of malaria. The sand drift, particularly during the summer season when water is low and anopheles-breeding heavy, blocks or deflects the exit of the streams and leads to the formation of stagnant or semistagnant lagunes where breeding of *Anopheles elutus* is ever abundant. It is the drift of

the sand from the south northward that gives the peculiar appearance to the mouths of all the streams along the coast. Invariably, the outlets of these streams are deflected northward and the point of entry into the sea varies from year to year, often from month to month.

The hill country in Judea and Samaria consists almost entirely of limestone, which can almost everywhere be seen cropping out at the surface through the meager covering of soil. There are few springs in these hills. The inhabitants depend largely on cisterns excavated in the limestone and cemented to render them water-tight. These cisterns, which are filled with rain water during the winter against the dry summer months, constitute an artificial source of anopheles-breeding where natural breeding-places do not exist.

The Galilee hills are separated from those of Judea by the Valley of Esdraelon. Here the outcrops are a mixture of limestone and basalt. Springs are more numerous than in the south, but cisterns still abound.

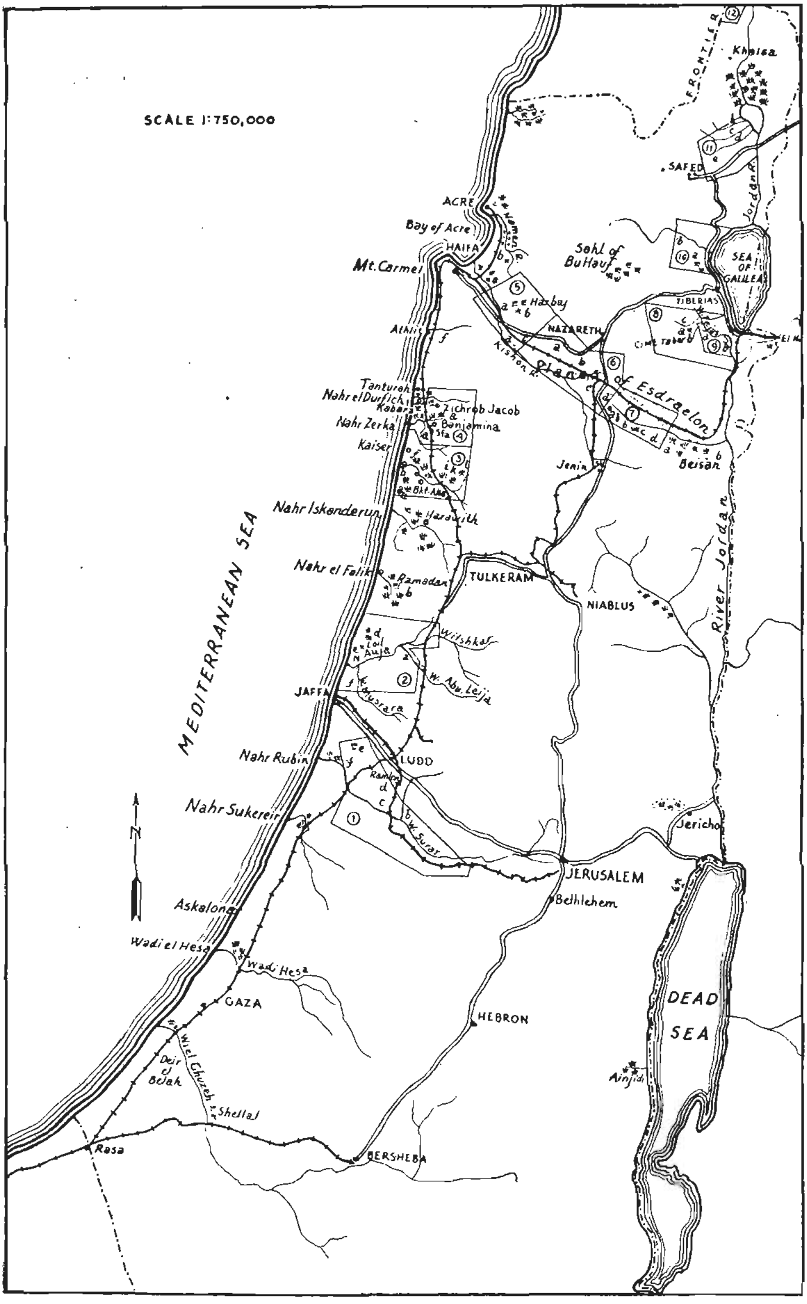
The Jordan Valley is a narrow depression, called the Ghor. It is a rift which begins at the base of the Anti-Taurus range in Syria and continues southward to the Dead Sea and the Gulf of Akaba. It was formed by a violent earth movement which dropped this narrow strip of land a few thousand feet below the plateaus on either side and as much as 1,200 feet below sea-level.

The river itself is extremely tortuous and falls rapidly. In the nine miles from the Sea of Merom to the Sea of Galilee it falls about 700 feet, from 100 feet above to 600 feet below sea-level; from the Sea of Galilee to the Dead Sea, a distance of 65 miles, it drops 700 feet more. The river itself lies too low for natural irrigation, but the valley is well watered by numerous streams which fall precipitously into the Jordan.

The drainage of the country is to the east and west. The watershed lies along the ridge of the Judean, Samarian, and Galilean hills, and follows approximately the Hebron-Jerusalem-Nazareth Road. On the west side of the ridge there are a series of streams almost parallel and equidistant which drain into the Mediterranean. On the east side, the wadis drain into the Jordan.

The numerous streams and tributaries shown on the map do not

MAP I



PALESTINE

Showing Swamps, Streams, and Wadis and M.R.U. Control Areas

imply that the country is well watered. These streams carry large volumes of water during the rainy season, but soon after the rains are over most of the wadis and tributaries are wholly or partly dry.

In a general way, the principal wadis on each side of the watershed resemble one another. The western group of wadis usually carry water at their origin and for some distance near the outlet. At their origin in the hills and foothills, various branches of the main wadi carry water from springs for a greater or lesser distance, according to the size of the spring. After leaving the foothills, the wadi beds are usually dry for a considerable distance, except for holes caused partly by the erosion of the winter flood, and partly by the shepherds who dig watering holes in the wadi bed during the dry season. As they approach the outlet, many of the wadis carry water throughout the year, either from springs which crop out near to or in the wadi bed, or from seepage from the sand dunes.

The wadis on the eastern side of the ridge fall more precipitously by a series of steps or cascades into the Sea of Galilee, the Jordan, or the Dead Sea. These wadis fall into two groups. Those south of Jerusalem are almost entirely dry after the rainy season, except for short distances where fed by springs. North of Jerusalem, on the other hand, many of the wadis are perennial, some of them carrying a considerable volume of water derived from large springs, often very numerous, which feed them all the year.

The watershed is not continuous. It is broken by the Valley of Esdraelon, which runs transversely across the country, dividing it into two unequal parts. The watershed, however, follows roughly the Jenin-Afuleh-Nazareth Road, the eastern side draining into the Jordan and the western into the Mediterranean Sea.

RAINFALL

Palestine is a country of seasonal rainfall. The rains begin about the middle or end of October, and last to the middle or end of March. During April there are a few spring showers, and from then to the middle of October there is practically no rain. But, although October 15 and April 15 define fairly well the extreme limits of the rainy season, its beginning and cessation are most irregular. The same may be said of the total and monthly precipitation during the

rainy season. The average amount of rainfall is about 25 inches. It diminishes from north to south and from west to east. The

TABLE I

Mean Rainfall at Various Stations in Palestine
(In Millimeters)

Situation	No. of Years	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Gaza, coast Judea....	10	110.0	49.8	36.8	6.9	7.9	0.8	0.0	0.0	0.8	20.8	80.8	104.9	418.7
Sarona, coast Judea...	10	191.0	73.9	36.8	6.9	4.8	0.0	0.0	0.0	0.8	14.0	112.0	178.8	619.0
Jerusalem, Judean hills	20	159.0	117.9	88.9	38.9	6.9	0.0	0.0	0.0	0.0	9.9	64.0	143.8	629.3
Hebron, Judean hills..	15	156.7	116.1	89.9	51.1	7.1	1.8	0.0	0.0	0.0	13.5	54.1	128.3	615.6
Haifa, coast Phoenicia	9	156.0	89.9	53.8	24.9	6.9	0.8	0.0	0.0	1.8	20.8	91.9	161.8	608.6
Nazareth, Galilee hills.	15	144.8	103.9	84.8	23.9	5.8	0.0	0.0	0.0	0.0	16.8	77.0	161.8	118.8
Tiberias, inland Jordan Valley...........	18	114.8	73.7	59.9	22.9	3.8	0.0	0.0	0.0	0.0	14.0	59.9	110.0	459.0

TABLE II

Comparison of Rainfall at Various Stations in Palestine*

Station	Yearly Average	1921–22	1922–23	1923–24	1924–25
Judean Hills:					
Jerusalem..................	24 years, 584	343	203	545	236
Judean Plain:					
Gaza......................	14 years, 411	461	314	330	334
Beersheba.................	4 years, 189	210	132	136	166
Tel Aviv..................	....	....	445	512	374
Mikweh Israel.............	....	472	390	447	416
Samaria-Phoenicia:					
Nablus....................	....	....	617	585	425
Tulkarem..................	....	....	663	624	521
Haifa.....................	13 years, 608	786	527	571	694
Valley of Esdraelon:					
Jenin.....................	4 years, 364	502	436	353	337
Jordan Valley:					
Tiberias..................	....	....	416	368	356
Average for all stations........	462	462	414	447	386

* Figures obtained through the courtesy of the Department of Agriculture, Government of Palestine.

This table shows the irregularity in the distribution of the rain. In general the rainfall in 1924–25 fell below that of the previous year, but in Haifa and other points along the Samarian coast it was considerably above that of the previous year.

months with the greatest amount of rain are December, January, and February. However, there are great variations in the total rainfall from year to year, as well as in the distribution of rain. Thus, the importance of rainfall as a factor in the formation of breeding-places depends as much—sometimes more—upon the distribution as upon the total volume (see Tables I and II).

The amount and the distribution of rainfall have a decided influence on the extent of the various types of breeding-places. As will be seen later, there are essentially two classes of breeding-places in the country, both of which are affected by the volume as well as by the distribution of the rains. Stagnant bodies of water breeding *A. elutus* constitute one group of breeding-places; others are slow or fast moving streams, breeding *Myzomia sergenti*[1] and *M. superpictus*. The former are found chiefly in the plains (large pools eroded by the winter floods in the clay or gravel beds of the streams) or along the coast (extensive bodies of stagnant water whose outlet to the sea is blocked by a sandstone ridge or sand dunes). The latter consist of springs and their streams, and are found chiefly in the foothills and narrow valleys.

Apparently, the quantity of the precipitation should determine the extent of the stagnant pools as well as the volume of the springs but this is not always the case. Often the rains come down in tremendous floods during a short period of time. The bulk of this water rushes down the barren limestone hills to the sea. The stagnant pools and land-locked basins receive large quantities of water, while comparatively little percolates through the rock to the source of the springs. On the other hand, if the rains are well distributed, the springs are swelled and the stagnant marshes are reduced.

The rain factor is thus a complicated one. When the total volume is above the average or average, the distribution factor is of the utmost importance, because on it depends whether serious outbreaks of malaria are to be expected throughout the country or in the coastal sections alone. The character of the winter rains thus enables one to predict with considerable accuracy the probable degree of mosquito prevalence in various parts of the country, and to prepare the requisite measures of control.

CLIMATE

The climate of Palestine is as diverse as its topography. In the small area encompassed in the boundary of the country, we have a range of climate from mildly temperate to tropical. In a general

[1] These species of anopheles are designated by their subgeneric names.

way, the country has two seasons, winter and summer. Throughout the country, January is the coldest and August the hottest month of the year. But the uniformity goes no farther.

Each physical division of the country has its distinct temperature and humidity range. In Jerusalem, for example, the typical station in the hill country, the lowest mean average temperature, in January, is 6.1° C. and the highest, in August, is 24.2° C. The corresponding temperatures in the Coastal Plain stations Haifa and

TABLE III

MEAN TEMPERATURES AT VARIOUS STATIONS

	Coastal Plain						Hill Country			Jordan Valley					
	Haifa Average 8 Years Mean			Gaza 1925 Mean			Jerusalem 1925 Mean			Tiberias Average 18 Years Mean			Jericho 1925 Mean		
	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.	Average
Jan.	9.6	17.0	13.2	6.6	16.0	10.8	2.7	9.5	6.1	8.6	17.6	12.6	7.8	19.0	12.0
Feb.	10.2	18.0	14.1	7.3	19.2	13.2	4.9	13.5	9.2	9.9	19.6	14.7	9.3	22.7	14.6
Mar.	11.4	20.6	15.8	11.8	23.4	17.6	9.7	20.5	15.1	11.6	22.2	16.6	14.9	29.8	20.7
Apr.	15.0	23.9	19.2	11.0	23.0	17.0	8.9	19.2	14.0	14.7	26.9	20.5	15.1	29.6	21.0
May	18.3	26.7	22.3	14.9	27.0	21.0	13.0	26.2	19.6	18.4	31.9	25.1	19.4	36.6	26.8
June	21.5	29.1	25.1	17.2	28.6	22.9	14.7	27.7	21.2	21.3	35.8	28.0	21.7	37.8	28.4
July	23.8	30.8	27.1	19.2	29.3	24.2	17.0	30.2	23.6	23.6	37.6	29.9	24.1	40.0	30.8
Aug.	24.5	31.7	27.6	20.0	30.3	25.2	17.8	30.6	24.2	24.3	37.6	30.5	24.5	40.4	31.2
Sept.	23.0	30.7	26.5	19.3	29.3	24.3	16.8	30.3	23.6	22.5	35.4	29.1	23.8	39.2	30.1
Oct.	19.7	27.6	23.9	17.4	28.9	23.2	15.1	27.0	21.0	20.6	32.3	26.7	21.9	35.6	27.0
Nov.	15.2	24.1	19.3	15.0	26.5	20.8	12.4	21.2	16.8	15.8	25.7	20.4	17.8	29.4	21.9
Dec.	11.0	18.4	14.7	10.2	21.0	15.6	9.3	17.1	13.2	11.7	20.4	15.8	13.2	24.9	17.2

Gaza are 13.2° C. and 10.8° C., and 27.6° C. and 25.2° C., respectively. In the Jordan Valley, we have 12.6° C, and 30.5° C. at Tiberias, and 12.0° C. and 31.2° C. at Jericho. There are corresponding variations between the mean minimum and the mean maximum temperatures in the different zones.

In general the hill country has a moderately temperate climate, the Coastal Plain is subtropical, while the Jordan Valley, particularly the region around Jericho, is distinctly tropical.

The three zones also have distinctive humidities. In a general way, the relative humidity is highest during the rainy season and lowest in May and October. Along the coast, the humidity is high and more or less constant throughout the year. In the hills, the

relative humidity drops rapidly after the end of the heavy rains, in March, reaches a low point during May and June, and then gradually rises again. The relative humidity in the Jordan Valley is lower than in either of the other zones, but here, too, there is a sharp drop after the rains are over, reaching the low point in May and June and then gradually rising.

The highest humidity occurs in January, the coldest month of the year. It is 76 in the Coastal Plain and Jerusalem, and 69 and 63 in Tiberias and Jericho, respectively. The lowest average humidity

TABLE IV

AVERAGE RELATIVE HUMIDITY AT VARIOUS STATIONS

	Coastal Plain			Hill Country	Jordan Valley	
	Gaza 10 Years	Sarona 10 Years	Haifa 9 Years	Jerusalem 20 Years	Tiberias 18 Years	Jericho 1925
Jan.	76	76	72	75.6	69.5	63
Feb.	74	75	71	70.3	66.5	54
Mar.	70.3	71	69	70.0	63.5	50
Apr.	67.6	70.6	69	57.0	58.5	49
May	67.6	71.3	70	49.0	55.6	37
June	70.0	73.0	72	52.0	46.5	44
July	71.0	73.6	71	56.6	49.5	46
Aug.	70.6	71.6	68	60.3	51.5	45
Sept.	70.6	69.6	67	60.3	53.0	50
Oct.	69.0	69.6	66	54.3	49.0	58
Nov.	71.0	71.0	69	65.0	60.0	68
Dec.	75.3	75.3	72	71.3	68.0	70

is in May, 70 in the coastal Plain, 49 in Jerusalem, and 46 and 44, respectively, in Tiberias and Jericho. The average humidities throughout the year for the various stations are shown in Table IV.

The prevailing winds are quite constant and fairly uniform throughout the country. The winds are usually westerly, as a rule northwest or west. They arise at about 10:00 A.M. and blow continually until about 5:00 P.M. Occasionally, the direction of the wind is from the east. These east winds, or "hamsins," are hot and dry and usually last about three days. They are very unpleasant and often in addition to the heat they bring a fine dust or sand which makes them almost unendurable.

The peculiar topography and the seasonal rainfall are largely responsible for the prevalence of malaria throughout Palestine. There

are few large permanent bodies of water; only three lakes, one of them highly saline (the seas of Merom and Galilee and the Dead Sea), and a few narrow streams called rivers which, excepting the Jordan and the Auja, deserve that name only when they are filled by the winter torrents. The primary physical factors which favor the development of anopheline breeding-places are the seasonal rainfall, the limestone formations, and the dunes. The heavy winter rains which fall during December, January, and February partly rush down the hills to the sea, and partly sink into them. The waters which run along the winter wadis into the plain erode deep holes in their beds, and give rise to pools which persist all year. As these wadis approach the sea, their course is usually blocked by sand dunes or outcrops of sandstone, and the water spreads out on the flat land, causing a series of extensive swamps at various points along the Coastal Plain, known as the Coastal Marshes. The waters which penetrate into the hills crop out at the foothills in the form of numerous springs, which run along in overgrown neglected creeks or wadis for greater or lesser distances. The inhabitants of the hill-tops supply the lack of natural storage by building cemented cisterns which catch and store the rain water.

The source of the mosquitoes and the consequent malaria in the various regions of the country—hills, foothills, and plains—is thus obvious. In the hills, e.g., Jerusalem, Safad, and other places, the cistern is the habitat of the anopheles, and is the principal cause of malaria. In the foothills, the numerous springs (only a few of which are utilized) and their overgrown wadis constitute the chief source of trouble (districts of Ekron, Merhavia, Nuris, Beisan and Yabniel, for example). In the flat plain along the coast, the erosion holes in the wadi beds tapping the ground water and the waters blocked by sand dunes (Kishon, Kabbara, Rubin) or sandstone outcroppings along the sea (Athlit, Tantura, Atta in Hedera) constitute the breeding-places of mosquitoes and the sources of malaria.

Aside from these breeding-places, there is one swamp of great magnitude—the Huleh Marshes above the Sea of Merom. This marsh is the worst and most extensive in Palestine, and makes the surrounding plain at the headwaters of the Jordan and at the Sea of Merom uninhabitable.

Most of the anopheles breeding-places in Palestine are due, however, either to century-old neglect by man or to man's carelessness. There are the numerous springs mentioned above with an abundance of water which runs to waste and forms over-grown streams (perennial wadis) and swamps offering ideal conditions for anopheles-breeding. There are also numerous watering-holes and primitive, leaky irrigation ditches which are responsible for a goodly portion of the malaria. A number of the Coastal Marshes were once drained by the Romans, but the canals were allowed to fall into disuse and the outlets to become blocked, so that the marshes reverted to their natural state.

The effect of the temperature, humidity, and other factors on the malaria of Palestine will be discussed in some detail when we consider the epidemiology of the disease.

CHAPTER II

SOCIAL, ECONOMIC, AND HEALTH CONDITIONS

Malaria may be classed among the social diseases of a country. It is now generally recognized to be, as a rule, most prevalent and of greater severity in countries of low social and economic status. Its prevalence diminishes in proportion as the economic and social levels are raised. In countries or sections of countries where living conditions are good, a high degree of anophelism may exist with a low degree of malaria. Consequently, to visualize the complete background of the malaria problem of a country we must know the social and economic conditions of its inhabitants.

Palestine is a country of mixed peoples, many religions, and all gradations of civilization. There are Jews from the Orient and the Occident, and side by side there are city Arabs, the peasants, and the roving Bedouins. There are Moslems, Jews, and Christians, people of every sect and denomination. And there are as well all gradations of culture, from the Nomadic, pastoral Bedouins to the most modern industrialized groups. A more heterogeneous population can hardly be found anywhere in the world.

In round figures there are at present about 150,000 Jews, 600,000 Moslem and Christian Arabs, and 100,000 Bedouins. The great majority of the Jews, whether city-dwellers or agriculturists, have a culture and living standard approximating those of western Europe. They are usually literate, often well educated, and have all the living requirements of the more civilized peoples of the West.

Alongside is the native Arab population, in the city largely illiterate and in the rural communities almost entirely so. Their standard of life in the city is low, and in the rural districts lower still. For the most part agriculture is still based on the share system—the tenant farmer hopelessly exploited by the effendi owner. As may well be expected under such conditions, production is at a minimum and farming methods archaic. The wooden plow is still used, manuring the fields is unheard of, and irrigation, where it exists, is most primitive.

The Bedouin is still in the pastoral stage. He lives chiefly by his herds and flocks, and moves from place to place with the change of season in search of water and pasture. His dwelling is the black tent of the Bible, and his home where he camps at the moment. The Bedouins travel westward and northward in the spring and summer, and eastward and southward in the fall before the onset of the winter rains. The effect of this constant migration on the prevalence and distribution of malaria is significant and will be discussed more fully later.

The housing conditions differ of course with the different groups. Most of the western Jews in the cities live in more or less comfortable quarters according to their earning capacity. The native-born Jews and a large number of the more recent immigrants live in very crowded quarters, often a whole family in a single poorly ventilated room. The bulk of the urban Arab population live in equally or even more crowded and poorly ventilated quarters.

In the rural section of the country, the contrast is even greater. Practically all of the older and some of the new colonists live in moderately well built and ventilated houses. The newer settlers, however, often spend from one to three years in tents or temporary wooden huts. The Arabs live in low mud houses, covered with mud and cow-dung roofs, usually without windows, and built to accommodate the animal, as well as the human, members of the family. The family usually sleep on reed mats on the dirt floor. Vermin, such as fleas, lice, and bedbugs, are abundant.

SANITATION

The sanitary conditions in the cities vary considerably. Central water supplies exist only in Jerusalem, Tel Aviv, and Hadar Hacarmel, a new section of Haifa. In Jerusalem the supply is far from adequate and is supplemented by the rain water stored in private cisterns. In most of the other cities, individual wells or cisterns (according to the location of the city, whether in the plain or the hills) are the sources of water supply. In some cities (Nazareth, Jenin) there are central springs from which the people get their water in earthenware vessels or tins.

Sewerage and sewage disposal systems are practically unknown.

Sections of Jerusalem and Haifa are canalized but the Jerusalem disposal plant is useless because of the high concentration of the sewage. The cesspit is universally used, and is a source of great annoyance to the inhabitants both on account of the foul odor whenever the pits are pumped out and the hosts of culices which breed in all of them. At this late date the inhabitants of even the more modern towns, including the capital, do not have the benefit of an adequate water supply and sewerage system.

Sanitation in the rural districts is conspicuous by its absence. In the larger villages there is, as a rule, a hole in the courtyard common to several houses. This hole is usually covered with flagstones with only a small oblong opening, which is never covered. Very often even this primitive type of latrine is lacking, and some corner of the village is favored by the majority of the inhabitants.

The water is, as a rule, obtained in earthenware jars from the village well or spring. Often the women folk walk a kilometer or more with the jar on their heads, bringing water from the most convenient source.

In the Jewish settlements the conditions vary. Practically all of them have a good water supply piped, from a spring or closed deep well, directly to the houses. The latrine condition is not so good. In most of the newer and some of the older settlements, good pit or pail latrines are found in from 75 to 80 per cent of the houses, in some of them in only from 30 to 40 per cent. But in all of them adequate latrines are provided in the schools, and are gradually being put into the houses.

The Bedouin knows nothing of latrines or water supply. He wanders with his flock or herd, drinking what he finds. He has a keen eye for the clear sparkling spring but, lacking that, he will use what he can get.

DIET

The diet of the native population also varies. In the urban and semiurban centers it is, as a rule, mixed and adequate: rice and mutton, grapes, figs, oranges, and melons in season, vegetables in season, most commonly cucumbers, vegetable marrow, cabbage, cauliflower, tomatoes, eggplant, and beans. Fat is consumed in the forms of clarified butter fat, olive and sesame oil (crude), and mutton fat.

In the rural districts the diet is much poorer, and its adequacy depends upon the season. When vegetables are abundant, they are eaten in large quantities; when scarce, they are not eaten at all. Durra bread, a variety of maize, and lebben, a fermented milk, constitute the chief articles of diet for most people. When milk is in season the lebben is preserved by drying, and in seasons of scarcity it is redissolved in water. The food is always eaten by hand, and gulped down very rapidly. Little attention is paid either to the preparation or eating of food.

In the Jewish settlements the food conditions are better, to a greater or smaller degree. Individual settlers prepare their food as they did in their country of origin, but here, too, the kind and quality of the diet varies with the seasonal abundance. Storage and preservation of foodstuffs is not yet practiced to any appreciable extent. In the newer settlements, and particularly in the larger co-operative groups, the diet is very bad. There is no attention paid to balanced diets, and to simplify the problem of food preparation, the diet is often onesided. Here, too, the food is gulped with little attention to palatability or digestibility.

It would seem that the native population has instinctively adopted a diet and a method of food preparation suitable to the climatic conditions of the country, and in large part comprising its domestic products. If they are ill-fed or undernourished, it is because their extreme poverty does not permit them even this simple diet in sufficient quantities. In the case of new immigrants, however, malnutrition is as often due to their clinging to their own food habits and ignoring the use of local products as to actual want.

GENERAL HEALTH CONDITION

Urban health conditions vary considerably with the towns and even with sections of the same city. The accompanying tables show the general mortality and the infant mortality in the different cities and various communities in the country. The high infant mortality is perhaps the best index to the existing sanitary deficiencies.

General health conditions in the Arab villages are poor. Aside from malaria, which is our special subject, there are a number of diseases which infect large parts of the population. Trachoma is extremely prevalent, and so is epidemic conjunctivitis. In many vil-

lages from 90 to 95 per cent of the children are infected with trachoma. Dysentery, particularly infantile diarrhea, is common. As a result, infant mortality is very high. Statistics from rural dis-

TABLE V

BIRTH-RATE, DEATH-RATE, AND INFANT MORTALITY IN SOME OF THE IMPORTANT CITIES*

	Jerusalem (62,778)†	Hebron (16,908)	Jaffa (48,663)	Gaza (17,829)	Haifa (25,082)	Nazareth (7,438)	Nablus (16,183)	All Cities 250,258
Births:								
1923	2,291	752	1,875	1,152	800	293	854	10,578
1924	2,555	1,084	1,933	1,252	1,232	306	1,031	12,209
1925	2,337	1,044	1,344	1,183	1,231	372	890	12,079
Birth-rate:								
1923	36.48	44.47	38.53	64.61	31.93	39.39	52.77	42.26
1924	39.54	62.30	38.60	68.24	47.75	39.97	61.91	47.40
Deaths:								
1923	1,139	676	1,089	745	483	134	542	6,477
1924	1,105	397	1,121	510	529	203	455	5,803
1925	1,435	577	1,032	583	586	160	518	6,762
Death-rate:								
1923	18.14	39.98	22.37	41.78	19.25	18.01	33.49	25.88
1924	17.10	22.81	22.38	27.79	20.49	26.52	27.32	22.53
Infant mortality:								
1923	141.85	355.05	210.66	275.17	227.50	105.80	189.69	217.99
1924	137.37	237.68	214.69	200.47	152.59	150.32	153.24	170.45
1925	156.61	232.21	273.06	246.83	161.65	126.34	188.76	194.13

* These figures are taken from the annual reports issued by the Department of Health of Palestine. The marked fluctuations in the figures are due chiefly to incomplete reporting. The figures are useful only to give a general idea of the health conditions as registered in the general and infant death-rates.

† Figures in parentheses denote population, 1923.

TABLE VI

BIRTH-RATE, DEATH-RATE, AND INFANT MORTALITY IN SOME OF THE RURAL DISTRICTS*

	Jerusalem District (30,486)†	Hebron District (37,733)	Jaffa District (22,702)	Gaza District (20,931)	Haifa District (26,184)	Acre District (28,143)	Nablus District (40,822)	Jenin District (31,514)	All Districts (except Beersheba) (411,255)
Births:									
1923	1,682	2,098	881	1,279	1,395	1,337	2,032	1,642	20,824
1924	1,841	1,660	1,133	1,603	1,484	1,623	2,325	1,799	22,746
1925	1,645	2,254	1,[illegible]25	1,450	1,414	1,543	2,356	1,796	23,400
Birth-rate:									
1923	55.17	55.54	38.80	61.10	53.27	47.50	49.77	52.10	50.57
Deaths:									
1923	1,105	1,083	327	974	516	556	813	731	10,517
1924	893	1,074	437	701	814	704	1,261	1,179	11,869
1925	1,006	1,786	471	689	723	768	1,426	1,039	12,849
Death-rate:									
1923	36.24	28.70	14.40	46.53	21.23	19.75	19.91	23.19	25.54
Infant mortality:									
1923	271.70	164.12	120.31	319.78	227	123.50	‡95.47	‡99.26	167.28
1924	237.68	206.02	118.27	200.47	190.03	157.11	153.24	171.76	187.72
1925	232.21	182.34	113.17	246.83	177.51	131.56	188.76	202.11	185.84

* These figures are taken from the annual reports issued by the Department of Health in Palestine.

† Figures in parentheses denote population, 1923.

‡ Reporting in the rural districts is even worse than in the cities. This accounts for discrepancies.

tricts are far less complete than those for cities, and deaths, particularly infant deaths, are not always reported. Nevertheless, the reports available show infant mortality rates of from 150 to 200 deaths per thousand births.

TABLE VII

COMPARISON OF DEATH RATES IN DIFFERENT RELIGIOUS COMMUNITIES

	Jews	Christians	Moslems*	Total†
Population:				
1923	93,000	74,000	495,000	662,013
1924	94,669	73,533	504,960	681,245
1925	120,559	74,781	515,894	719,508
Births:				
1923	3,276	2,566	25,147	31,402
1924	3,626	2,970	28,025	34,945
1925	4,000	2,777	28,211	35,471
Birth-rate:				
1923	35.2	34.7	50.8	47.43
1924	38.3	40.4	55.5	51.53
1925	33.2	37.2	54.7	49.31
Deaths:				
1923	1,310	1,135	14,424	16,994
1924	1,193	1,235	15,098	17,058
1925	1,817	1,406	16,119	19,611
Death-rate:				
1923	14.1	15.1	29.1	25.67
1924	12.6	16.8	29.9	25.04
1925	15.1	18.8	31.2	27.35
Infant deaths:				
1923	412	346	5,012	5,802
1924	383	451	5,577	6,458
1925	525	451	5,656	6,693
Infant mortality:				
1923	125.8	134.8	199.3	184.76
1924	105.7	151.9	199	184.80
1925	131.2	162.4	200.5	188.64
1927	115.3	187.2	216.7	200.5

* Exclusive of nomadic tribes.

† Including about 10,000 of other religions.

In the Jewish population in general and in the rural settlements in particular health conditions are decidedly better. There is at least one resident physician to each of the larger villages and to groups of the smaller ones. Eye diseases are treated regularly and systematically. More attention, although far too little, is given to infant-feeding, and consequently the infant mortality is considerably lower than among the Arab population. Intestinal infections are much less common than in the cities.

THE CLUSTERED VILLAGE

The character of the rural settlements is a matter of considerable moment from the standpoint of malaria. The agricultural population of Palestine lives in villages and moves in groups. The modern settlements, Jewish and German, have developed on the same principle. The chief reason is safety. The village is much more easily watched and protected against raids than the isolated homestead. For obvious reasons these villages and settlements are, when at all possible, established near a spring or stream. Water is rare in Palestine and is a vital thing. It must be watched over just as carefully as human beings and animals. But the clustered village in close proximity to a spring and wadi creates a condition most favorable to the spread of malaria.

It is evident even from this brief sketch of the social and economic status of the population that there are several factors which favor a high endemicity, and increase the danger of epidemic extension of malaria. As as result of the generally low economic status of the bulk (90 per cent) of the rural population, their poor living conditions, and low-grade diet, they constitute an ideal medium for the maintenance of a high malaria endemicity. At the same time the wandering of nomadic Bedouins hither and thither across the country, coupled with the influx of large numbers of non-immune people who live under poor conditions during the first two or three years at least, create the possibility of epidemic extension of the disease throughout the limited confines of this small country.

CHAPTER III

THE ACTUAL AND POTENTIAL BREEDING-PLACES OF ANOPHELINE MOSQUITOES

Palestine comprises three main[1] divisions: Judea, Samaria, and Galilee, which we shall follow for the sake of convenience in a more detailed description of local conditions prevailing in each part of the country.

JUDEA

This district extends roughly from Gaza in the south to a point north of the river Auja and from the Mediterranean to the Dead Sea and the Jordan River. From the malaria standpoint, the portion west of the watershed to the Mediterranean is by far the most important.

a) *The eastern slope and Dead Sea region.*—On the east side the hills dip sharply from 3,000 feet above to 1,300 feet below sea-level, over a distance of only 20 miles. The slopes of the hills are cleft by a series of deep, almost parallel wadis, running east or southeast into the Jordan or the Dead Sea. In the winter, during the heavy rains, these wadis are torrential streams, while in the summer most of them are dry. Of the whole series of wadis, the only ones having perennial streams are Wadi Kelt and Wadi Umm-Bagheq, which are fed by large springs, and Wadi Auja and its tributaries, which carry water for short distances.

No mosquito survey has been made of Wadi Umm Bagheq, but there are many observations of Wadi Auja and Wadi Kelt. These wadis (and this is true of all the streams in this area) are prolific sources of both *M. superpictus* and *M. sergenti.* Austen reports prolific breeding of *M. palestinensis* (*superpictus*) in both the Auja and Kelt, and Buxton reports both *superpictus* and *sergenti* in the Kelt.

The rocky nature of these wadis and wadi beds renders control extremely difficult. One often sees the larvae attached to a rock on the side of the wadi, unaffected by the rapid stream in the middle.

[1] The Valley of Esdraelon, which for convenience is treated as a separate section, actually belongs to Galilee in its western and to Samaria in its eastern part.

Sultan near Jericho) *superpictus* and *sergenti* breeding is abundant in the late summer. In the stagnant pools near Ein-es-Sultan, and along the banks and in the aquatic vegetation of the Jordan, *A. elutus* (*maculipennis*) breeds in great abundance.

What scanty population is to be found in this entire area is concentrated near the small cultivable regions around the springs. Since it is in these regions that anopheline breeding is most prolific, it is evident that malaria would be extremely prevalent there.

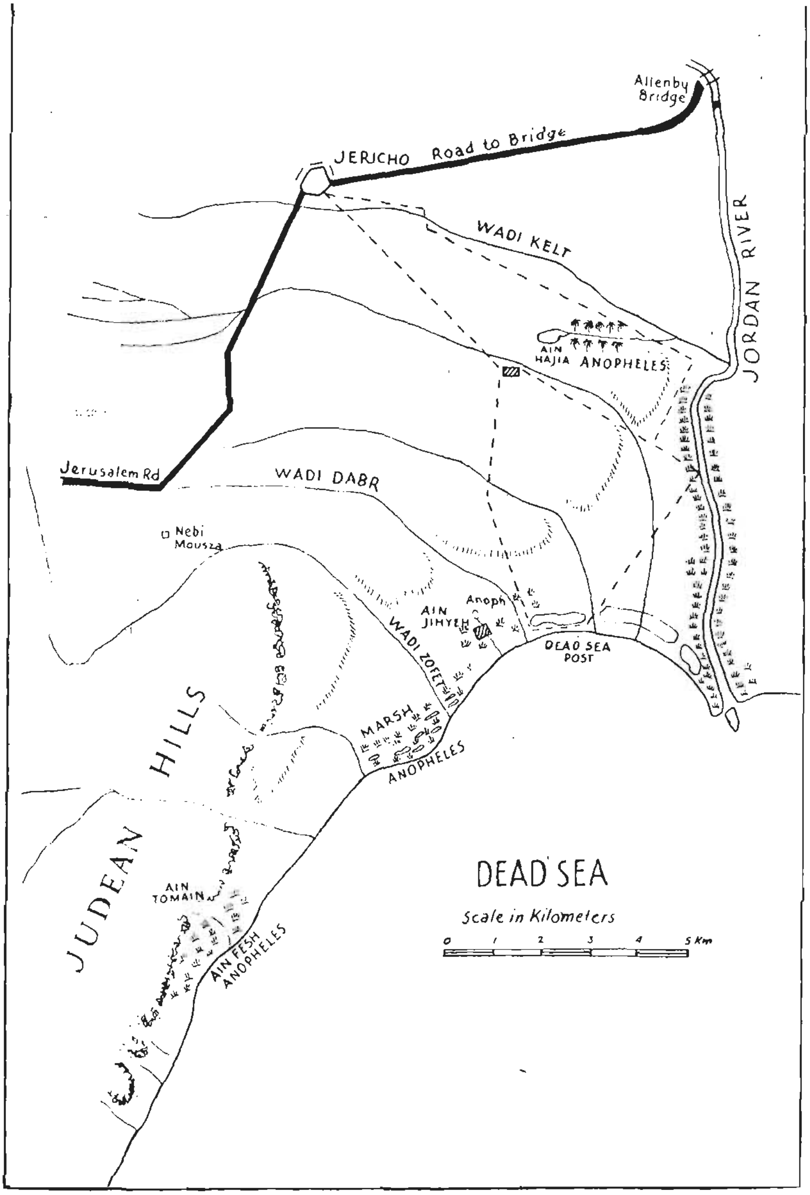
A preliminary survey of the Dead Sea has been made by Mieldazies. The survey was made during March. The only habitations were a few huts known as the Dead Sea Post, from which small boats were run to the eastern shore for transporting grain and cattle from Transjordan to Palestine. A few Bedouins from the Gaza and Beersheba districts brought their camels there during the winter months for pasture.

Along the western shore of the sea region there is a narrow strip of plain about 500 meters wide, from which precipitous cliffs of sandstone rise to a height of 300 meters. To the north of the sea, is the broad plain extending to the Jordan Valley. This plain is cut by interlacing stream beds into a succession of cone-shaped hills. The soil of this plain for several kilometers north of the sea is, except along the banks of the streams, around springs, and in the marsh areas, too salty for vegetation.

The Jordan River, to the east of the Dead Sea Post, overflows its banks during the rains and causes extensive swamps, which gradually dry up after the rains are over.

Mosquito-breeding was observed nearly everywhere: in the marshes and hoofprints around Ein-Feshkhah, in the Wadi Jofet Zeben, and Wadi Dabr. Both anopheles and culex were breeding very prolifically. In the waters of the Ein Jeheiyeh no breeding was found, probably on account of the presence of numerous small fish, but in the small marshes round about, both anopheles and culex were found. Anopheles larvae also were found in the sluggish flowing irrigation canal at the Ein Hajla and in the cracks and crevices of the cemented sides of the distributing reservoir.

This survey shows that even the area bordering on the Dead



North and West Coasts of Dead Sea

Sea, which has been considered dry and arid, may prove to be highly malarious if a large group of people is brought in for the development of the Dead Sea resources, unless the necessary precautions for malarial control are taken. Apparently, the most suitable place for settlement or labor camps will be the present Dead Sea Post, since no anopheles-breeding has been found within several kilometers of it. Of the anopheles encountered only *M. superpictus* has been identified, but *M. sergenti* and *M. multicolor* most certainly breed there as well.

b) *The plateau.*—The greater part of the Judean plateau consists of a stony woodland with cultivable land here and there. Nowhere in this area are there any perennial streams. On the entire plateau the only signs of permanent water are the Pools of Jerusalem, the Pools of Solomon, and a few springs and small wadis of which the Wadi-El-Arub between Bethlehem and Hebron is the largest.

The principal source of malaria in this region is the cistern, which offers ideal breeding conditions for the northern mosquito, *A. bifurcatus*. This species of mosquito was responsible for the malaria which, until three or four years ago, was so highly prevalent in Jerusalem, Ramalla, and other highland towns and villages which depend on the cistern for their water supply. However, the few small creeks, such as Wadi Fukim, west of Bethlehem, were, and to an extent still are, the sources of a goodly amount of malaria.

c) *The Maritime Plain.*—The Judean portion of the Maritime Plain begins with Wadi Ghuzzeh at the south, and extends to the Auja River at the north. The plain varies from 20 to 30 miles in width, and is drained by a series of deep, transverse wadis, almost equidistant, which empty into the Mediterranean. Near the coast the plain is for the most part flat, but farther east it rises slowly, through low undulating hills, to the Central Plateau.

From the point of view of malaria, the streams or wadis which drain this area constitute the important feature. There are five principal water courses, resembling each other closely. They originate in the highland, wind their way into the plain, and there follow a westerly, northwesterly course to the sea. After the winter rains cease, all of these wadis carry a greater or lesser amount of water

at their origin from sources which empty into them. These sections of the wadis favor the breeding of *M. sergenti* and *M. superpictus*. Beyond that, the stream beds are dry for considerable stretches,

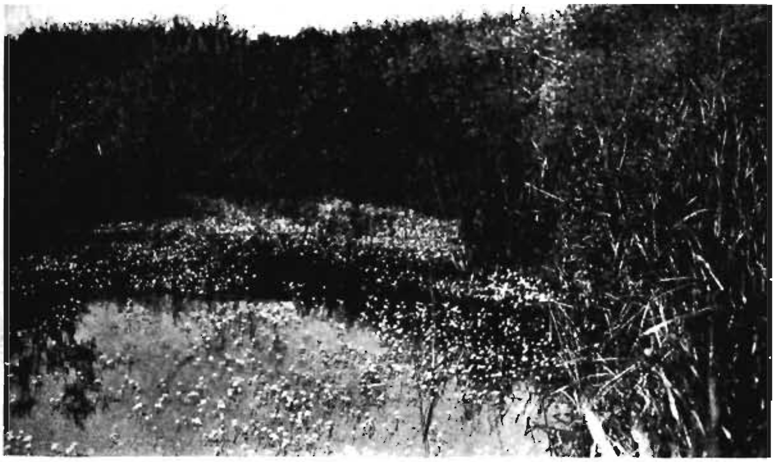
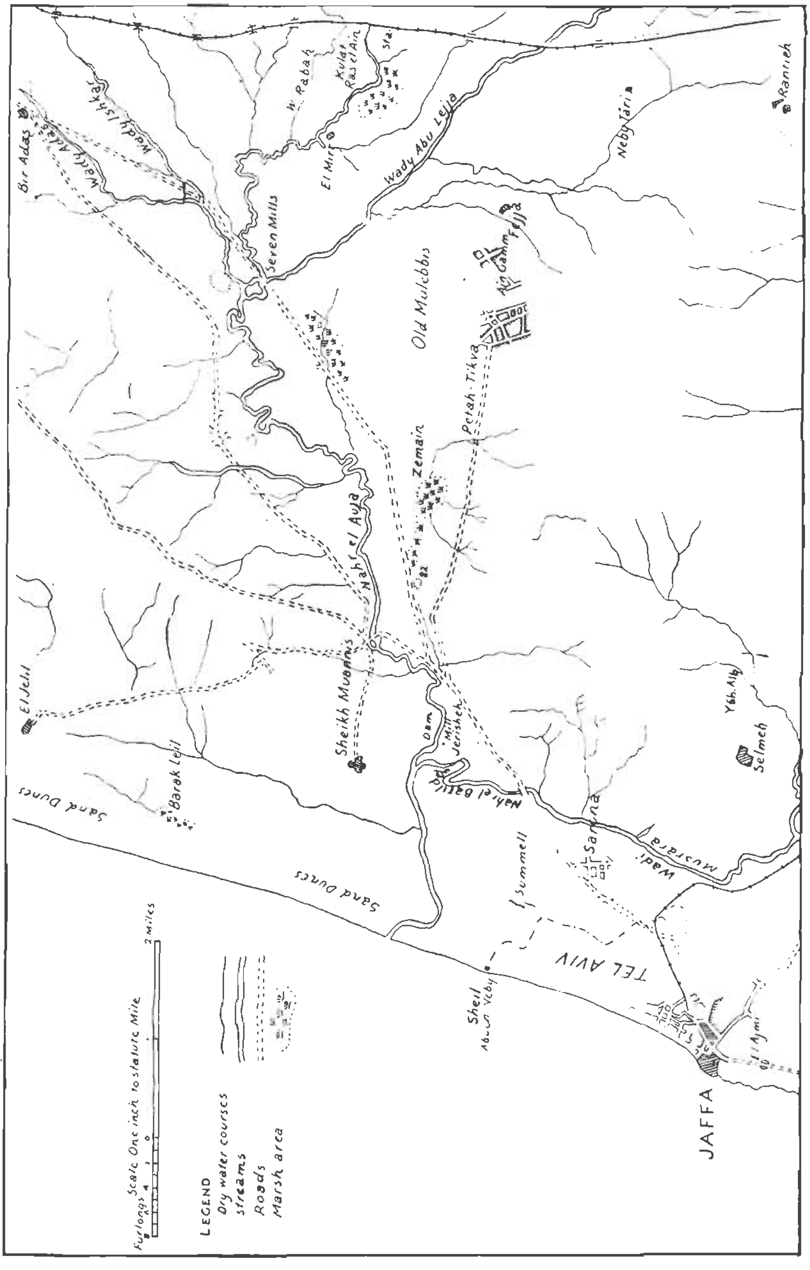


FIG. 3.—Pool in winter wadi overgrown with ranunculi

FIG. 4.—A cleaned pool in winter wadi

except for shallow or deeper erosions or watering pools in their beds, which when overgrown, as they usually are, favor the breeding of *A. elutus*. As the wadis approach the sea, the water-containing ero-

MAP III



AUJA RIVER AREA, JAFFA

sion pools become more frequent, and near the outlet the wadis again carry water from springs or seepage from sand dunes. As a rule the outlets of these wadis to the sea are partly or completely blocked by sand bars, giving rise to stagnant conditions favoring the growth of weeds and aquatic plants, and constituting an ideal environment for the breeding of *A. elutus*, *A. algeriensis*, and *A. hyrcanus*.

FIG. 5.—Typical coastal marsh, showing land-locked basins

Beginning from the south, the principal wadis are: Wadi Ghuzzeh, Wadi Hesi, Wadi Sukereir, Nahr Rubin, and Nahr-el-Auja.

Several of the common malaria transmitting anopheles breed in these wadis. In Wadi Musrara for example there is heavy breeding of *M. superpictus, M. sergenti*, and *A. elutus*. In the aquatic vegetation and along the banks of the Auja, one finds a fair amount of breeding of *A. elutus*. At Ras-el-Ein there is active breeding of *M. superpictus* and *M. sergenti*. In the erosion holes of Abulejja and Ishkar, *A. elutus* and *A. algeriensis* breed prolifically.

Detailed description of a typical stream—Nahr Rubin.—A more

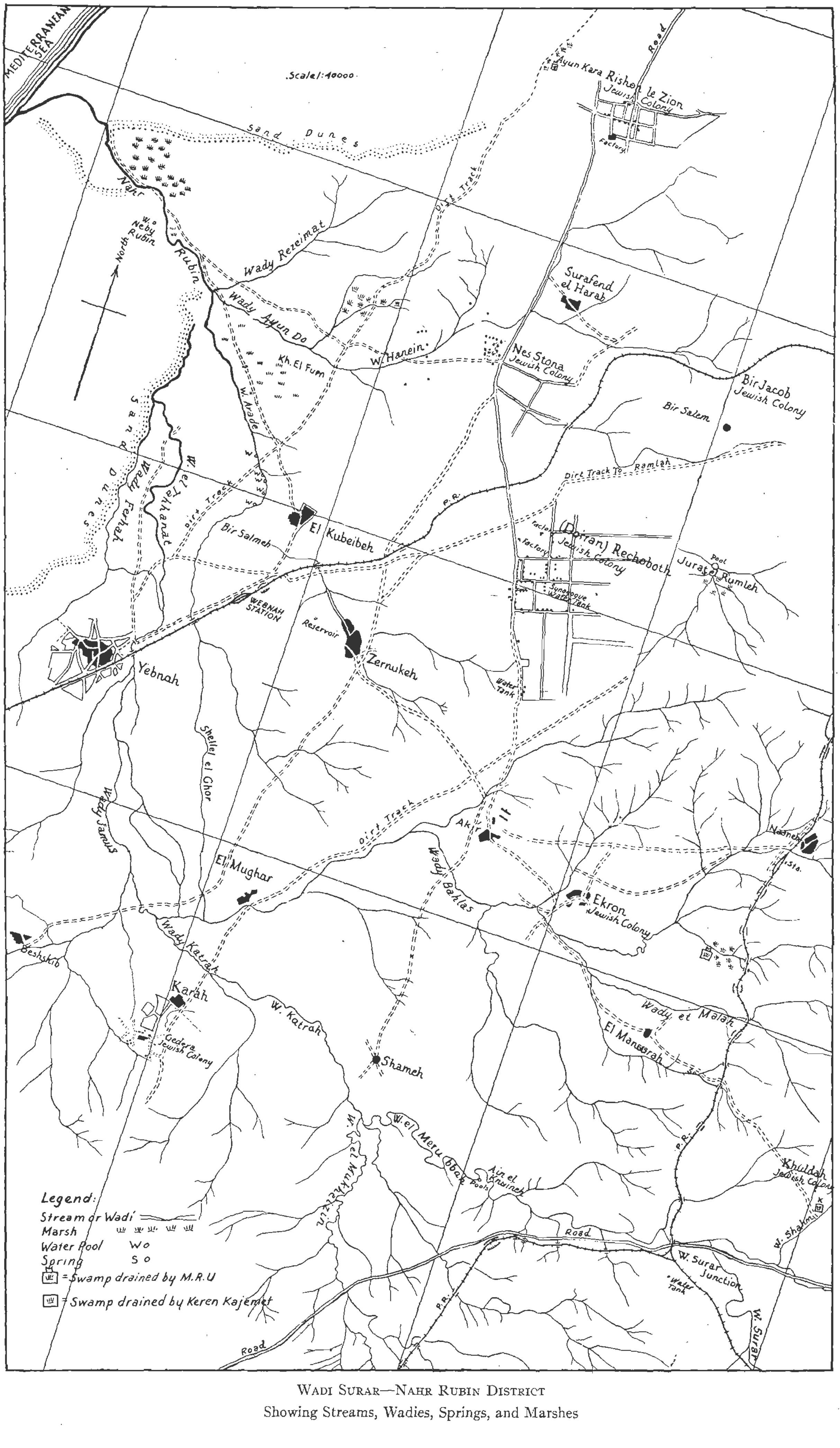
detailed description of one of these wadis, which has been observed by us with some care for a period of two years, will serve as a type for the other wadis of this area, and will illustrate the relation of these water courses to the malaria of the region through which they pass. Part of this wadi is known as Wadi Surar, part as Wadi Katra, part as Wadi Rubin; near its end it is called Nahr Rubin.

Wadi Surar (afterward Nahr Rubin) has its origin in the foothills of Judea, near Bireh. Various small spring-fed tributaries feed it on either side, but those near Artuf, Kfar Uria, Hulda, Seged, and Ekron have been more especially studied. The main Wadi Surar enters the plain near Artuf and runs in a westerly direction, paralleling the railway line as far as Wadi Surar station. Thence it passes beneath the railway and pursues its winding course once more in a westerly direction to Yabneh. Beyond Yabneh it turns to the north and then to the west, falling into the Mediterranean.

The bed of the upper part of the wadi is dry. From the point where it enters the plain until Artuf station, only three or four pools remain after the rains, and these dry up sooner or later in the summer. Near Artuf, however, there passes a small tributary, Wadi Metlak, which originates from springs in the neighboring foothills, and falls into the Surar. In seasons of heavy rainfall this wadi dries up very late (about August), and has been the source of a high incidence of malaria in Artuf. The type of anopheles breeding in this wadi is *M. superpictus*.

Between Artuf and the Surar station the wadi bed is dry, but it contains over thirty large pools, most of which persist practically all year, are covered with aquatic vegetation, and breed actively *A. elutus*, *A. hyrcanus*, and *A. algeriensis*. The villages most affected by these pools are Surar and Ein Shemes, which are only 2 and 1½ kilometers distant, as well as Beradj and Seged, which are a little farther away. Near the latter there runs another tributary, Wadi Seged, fed by springs and carrying water most of the year. *M. superpictus* breeds actively in this stream. In addition to these villages, directly affected by the Wadi Surar, there are the villages Kfar Uria and Hulda located near springs and tributary wadis falling into the Surar. All of these villages were highly malarious before control work was started. The mosquitoes found in these wadis are

MAP IV



Wadi Surar—Nahr Rubin District
Showing Streams, Wadies, Springs, and Marshes

M. superpictus, *M. sergenti*, and *A. elutus*, according to the character of the breeding place.

For about 2.5 kilometers, immediately beyond the Surar station, there is a series of large permanent pools in which anopheles mosquitoes breed prolifically. These pools are a serious source of malaria to the station and neighboring villages. Beyond that, for about 15 kilometers, to Yabneh, the wadi is dry, except for a few shallow pools which dry up early in the spring in years of low rainfall, and remain until July in years of heavy rainfall. Along this part of the wadi the prevalence of malaria varies from year to year according to the rainfall. In the villages Ekron and Naaneh located on the spring-fed tributary, Wadi Melat, and in the village Mansurah near Wadi Mansurah, malaria was always highly prevalent until control was effected.

From Yabneh the wadi bed becomes quite deep, and the pools again become more frequent. Most of these, however, dry up by July. As the wadi approaches the sand dunes, it receives seepage from the dunes and the flow from springs and swamps on the north side. It is at this point that the wadi becomes a perennial stream for its entire length to the sea. The outlet is partially and often wholly blocked by the sand drift, as is the case with all these coastal streams, and the flow is, therefore, sluggish. The surface of the stream is covered with potamogeton and the banks with reeds, and there are favorable places for anopheles-breeding along its whole length. *A. elutus* and *A. hyrcanus* breed prolifically.

In addition to Nahr Rubin, there are three tributaries which empty into it at this point: the one, Wadi Arad, which comes from the east, passing near el-Kubebe, has the same appearance as parts of Wadi Surar: many overgrown pools, all breeding *A. elutus*. The others are short wadis arising from the spring-fed swamps close by the river bank.

This region is highly malarious. During the Nebi Rubin festival, numerous cases of malaria occur among the visitors. Otherwise, this region is sparsely inhabited by a few Bedouin tribes.

This, then, is a typical picture of a coastal or winter wadi. It carries water only in the winter, dries up in parts after the rains, but there remain a number of pools of greater or lesser dimensions which,

becoming covered with ranunculi or potamogeton or both, offer excellent breeding places for anopheles, chiefly *A. elutus*, *A. hyrcanus*, and *A. algeriensis*. It is around these pools and the small water

FIG. 6.—Wadi Musrara

FIG. 7.—Wadi Abulejja before drainage

carrying tributaries of these wadis that the malaria of this region is focalized.

The parallelism between the proximity to water courses and

Place†	Wadi	Branch Of	Location	Distance (in Kilometers)	Condition of Wadi	Blood Index	Spleen Index	Examined By	Remarks
Esdud	Beit Duras	Sukereir	plain	2.0	dry	....	0.0	....	
Falujeh	Beit Duras	Sukereir	plain	0.0	dry	0.0	13.0	....	
Suafir North	Beit Duras	Sukereir	plain	1.0	dry	0.0	0.0	....	
Jelediyeh	Beit Duras	Sukereir	plain	0.0	dry	0.0	30.0	....	
Burka	Beit Duras	Sukereir	plain	1.0	dry in May	9.0	60.0	....	Conditions vary with amount of rain
Ijseir	Beit Duras	Sukereir	plain	1.0	dry in July	12.0	18.0	....	
Beit Duras	Beit Duras	Sukereir	plain	1.0	dry	0.0	16.0	....	
Tel-el-Turmas	Bursheim	Sukereir	plain	0.0	holes dry in May	18.0	100.0	....	In years of heavy rain malaria is highly prevalent
Yazur	Mesmiyeh	Sukereir	plain	1.0	dry	0.0	40.0	....	
Kastinieh	Bursheim	Sukereir	plain	0.0	dry	0.0	55.0	....	
Batani, Sherkiyeh	Bursheim	Sukereir	plain	1.0	dry	0.0	71.0	....	
Batani, Gharbiyeh	Bursheim	Sukerier	plain	0.5	dry	23.0	42.0	....	
Balin	Bursheim	Sukereir	....	2.0	dry	18.0	46.0	....	
Deir-el-Bela	....	Ghuzzeh Marsh	plain	.... 1.0	wet in July	16.0	88.0	....	
Kfar Uria	Bijis	Surar	foothills	1.0	wet	0.0	25.0	M.R.U.	
Hulda	Bijis	Surar	foothills	0.5	wet	9.7	25.0	M.R.U.	
Naaneh	Melat	Surar	plain	2.0	marsh	30.3	94.2	M.R.U.	
Eccron	Melat	Surar	plain	2.0	marsh	7.9	9.4	M.R.U.	
Besheit	....	N. Rubin	plain	2.0	dry	8.0	54.0	....	
Mughar	Katra	N. Rubin	plain	1.0	dry	10.0	20.0	....	
Katra	Katra	N. Rubin	plain	0.0	wet	10.9	91.0	M.R.U.	
Gedera	Katra	N. Rubin	plain	1.0	wet	9.3	37.0	M.R.U.	
Yabneh	Rubin	N. Rubin	plain	1.0	dry	50.0	10.0	....	
Ein Ganim	Abulejja	Auja	plain	2.0	wet	5.7	50.0	M.R.U.	
Fejaz	Abulejja	Auja	plain	1.0	wet	25.0	96.4	M.R.U.	
Mahneh Yehuda	Abulejja	Auja	plain	2.0	wet	2.7	37.5	M.R.U.	
Kfar Saba	Adas	Auja	plain	2.0	wet	7.9	38.4	M.R.U.	

* All the examinations, except those *otherwise indicated*, were made by Dr. Carley of the Malaria Survey Section.

† The villages in the plain near dry portions of the wadis are practically free of malaria; others near wet portions are highly malarious. The survey on which some of these figures are based was made in May and June, 1923, by Dr. Carley of the M.S.S. The year 1923 was a year of drought and the wadis and pools dried early. The high splenic index in some of the villages near dry wadis is due to the high malaria rate in 1921 and 1922 when the pools dried up *late in the summer or not at all.* Owing to lack of treatment the latent malaria in these villages remains high despite the absence of new infections.

malaria prevalence is demonstrated by Table VIII, which gives a summary of blood and spleen rates in various villages in the plain and their proximity to wadis. It will be noted that the villages in the foothills near a spring wadi have the highest rates, while those farther removed from the stream beds have the lowest.

SAMARIA

This area may be conveniently defined as bounded by the Mediterranean on the west, the Jordan on the east, the Judean boundary on the south, and the southern border of the Plain of Esdraelon on the north. It forms what is almost a square of about forty miles on each side. Like Judea, this district has three divisions: the Jordan Valley, the Central Plateau, and the Coastal or Maritime Plain. The Central Plateau differs from that of Judea in that the hills are not compact, but broken and interspersed with plains. As in Judea, the eastern slope is much steeper than the western, but it is not nearly so poorly watered and desert-like as is the eastern slope of the Judean Hills. The western slope falls by easy gradients to the Coastal Plain.

Eastern division.—On the eastern side there are several important wadis, some of which carry permanent streams. The most important of these are Wadi el Malih and Wadi Farah. Both wadis furnish extensive breeding areas for *M. superpictus* as well as *M. sergenti; M. multicolor* also breeds in Wadi Malih.

The plateau.—In the northern part of the plateau there is a series of plains among a loose mass of hills. On the northern end is the plain which lies between Mount Gilboa and the Carmel range, extending from the Plain of Esdraelon to Jenin; there it rises slowly for a number of miles into the plateau. This area is drained partly by Wadi Shemma into the Kishon, in the Valley of Esdraelon; and partly by Wadi Selhab into Wadi Khudeireh or Nahr el Mefjir to the west. Southeast of this plain is a large depression from three to four miles in diameter called Merj-el-Ghuruq, which is completely hill-locked and remains under water for a good part of the year, particularly in years of heavy rainfall. South of Wadi Nablus are the Mukneh and Salim plains, drained respectively by Wadi Kanah, flowing westward, and Wadi Bidan, a branch of Wadi Farah. In the wadis around Jenin *M. superpictus* has been found by Buxton;

in Merj-el-Ghuruq *A. elutus* breeds in abundance; the anopheline fauna of the other places has not been studied as yet.

The Maritime Plain of Samaria is a continuation of the Judean Plain. It varies in width from 9 miles at the south to 2 miles at Zammarin and only a few feet at Carmel Point. Like the Judean Plain it is drained by a number of parallel wadis falling into the Mediterranean. The most important of these are Nahr el Falik,

FIG. 8.—Birket Ramadan viewed through cut in sandstone—presumably Roman, one of the landlocked coastal marshes in Samaria.

Nahr Iskanderunch, Nahr el Mefjir, Nahr ez Zerka (crocodile river), and the Nahr el Dufleh.

Prevalence of malaria.—There is as yet no complete survey of the malaria prevalence in the various parts of Samaria. In the Jordan Valley and the cultivable part of Wadi Farah, malaria is highly prevalent. It is no exaggeration to say that 100 per cent of the Bedouins cultivating these areas are infected with malaria. An examination of some members of these tribes who invade the Plain of Esdraelon during the summer showed a parasite rate of 25 per cent and a spleen rate of 98 per cent.

In the hills of the plateau, malaria, if present, is due almost en-

tirely to cistern-breeding. But in the plains—Jenin, Ghuruq, Salim—malaria is highly prevalent as a result of unregulated wadis, springs, and irrigation canals. Until the British occupation, Jenin itself was highly infested with malaria. The regulation of the springs and the irrigation canals around Jenin by the army has practically eliminated the disease. Nablus and Tulkarem, the two other principal towns in Samaria, are free from malaria.

TABLE IX

Blood and Spleen Indices in Villages of the Coastal Plain—Samaria (Children under Thirteen Years)

Village	Blood Index		Spleen Index	
	No. Examined	Per Cent Positive	No. Examined	Per Cent Positive
	Arab			
Hassan Said	34	10.2	10	80.0
Faukra	40	10.0	27	66.6
Cherkas	15	53.3	14	71.4
Dameira	46	30.4	46	50.0
Abu Jemain	6	16.7	6	50.0
Tantura	86	9.3	87	47.1
	227	17.2	190	86.8
	Jewish			
Shuni	60	5.0	60	15.0
Gan Shmuel	25	4.0	25	28.0
Nahliel	52	0.0	21	42.8

The entire Coastal Plain is highly infested with malaria, so much so that there are large uninhabited, or only sparsely inhabited, areas, particularly nearer the coast. An idea of the malaria prevalence in this region may be obtained from Table IX, which gives the results of blood and spleen examinations in various villages along the plain.

During the last three years a great deal of work has been done, details of which will be given later, toward eliminating the sources of malaria along the Coastal Plain. The Athlit marshes and Wadi Dustreh have been drained by the Palestine Salt Company, which has a concession to produce salt. Further south, the Kabbara and

the Zerka marshes are now being drained by the Palestine Jewish Colonization Association. Southward the Malaria Research Unit, in co-operation with the settlements Hedera and Gan Shmuel, has drained the marshes around Cherkas, as well as Wadi Khudeireh. The full realization of these projects will eliminate some of the principal sources of malaria along the Samarian coast, and once again render this fertile region habitable and fruitful.

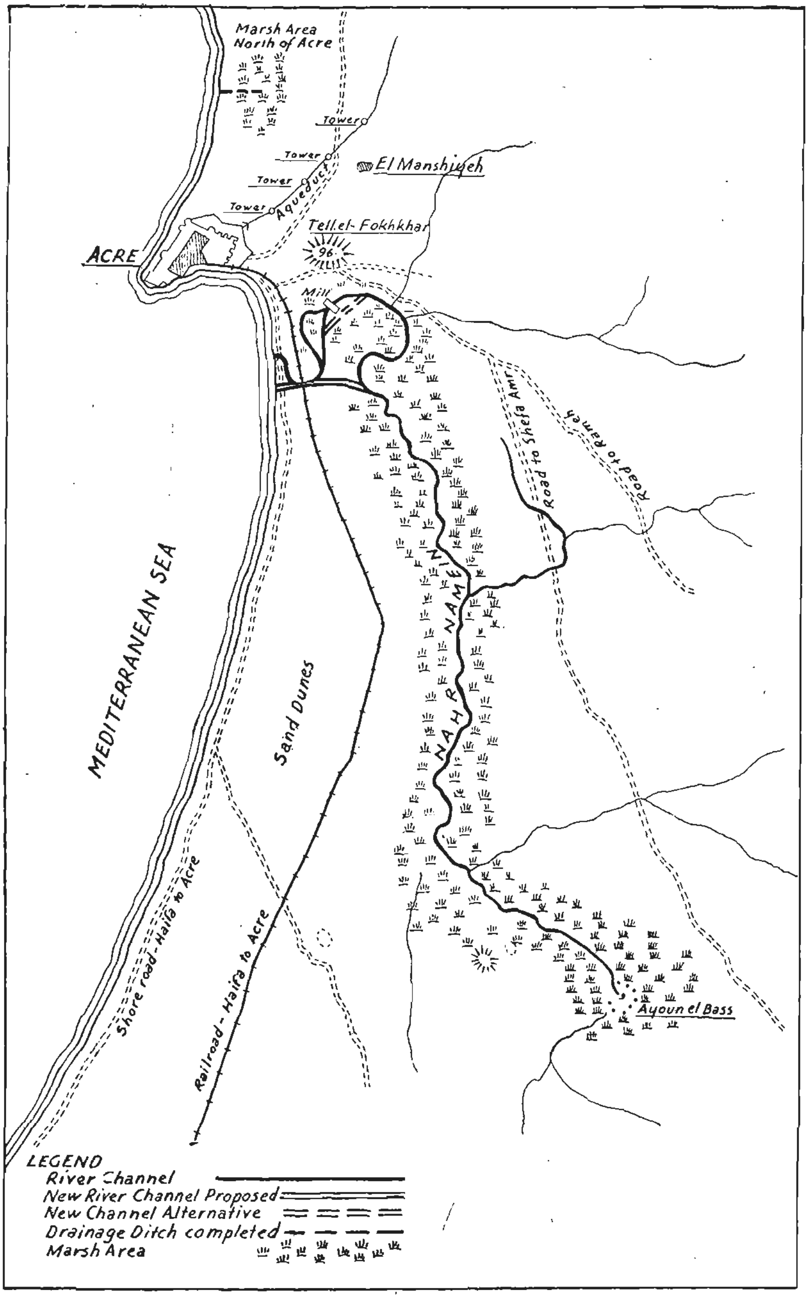
FIG. 9.—A view of the Kabbara Marsh, in the region of Nahr ez Zerka, in Samaria

PLAIN OF ESDRAELON

The Plain of Esdraelon forms the physical boundary between Samaria and Galilee. It is really an extension of the Plain of Sharon, cutting the country transversely from Haifa to the Jordan. For our purpose it will be convenient to treat this plain together with that of Beisan as a separate division, although actually the former is a part of Galilee, while the latter belongs to the district of Samaria.

The Plain of Esdraelon consists of three parts, each drained by a system of wadis. One division is the Coastal or Acre Plain lying between Haifa and Acre and between the sea and the foothills of the Lower Galilee range. This plain is drained principally by the Namein

MAP V



Swamp, Namein River Area, Acre, Haifa

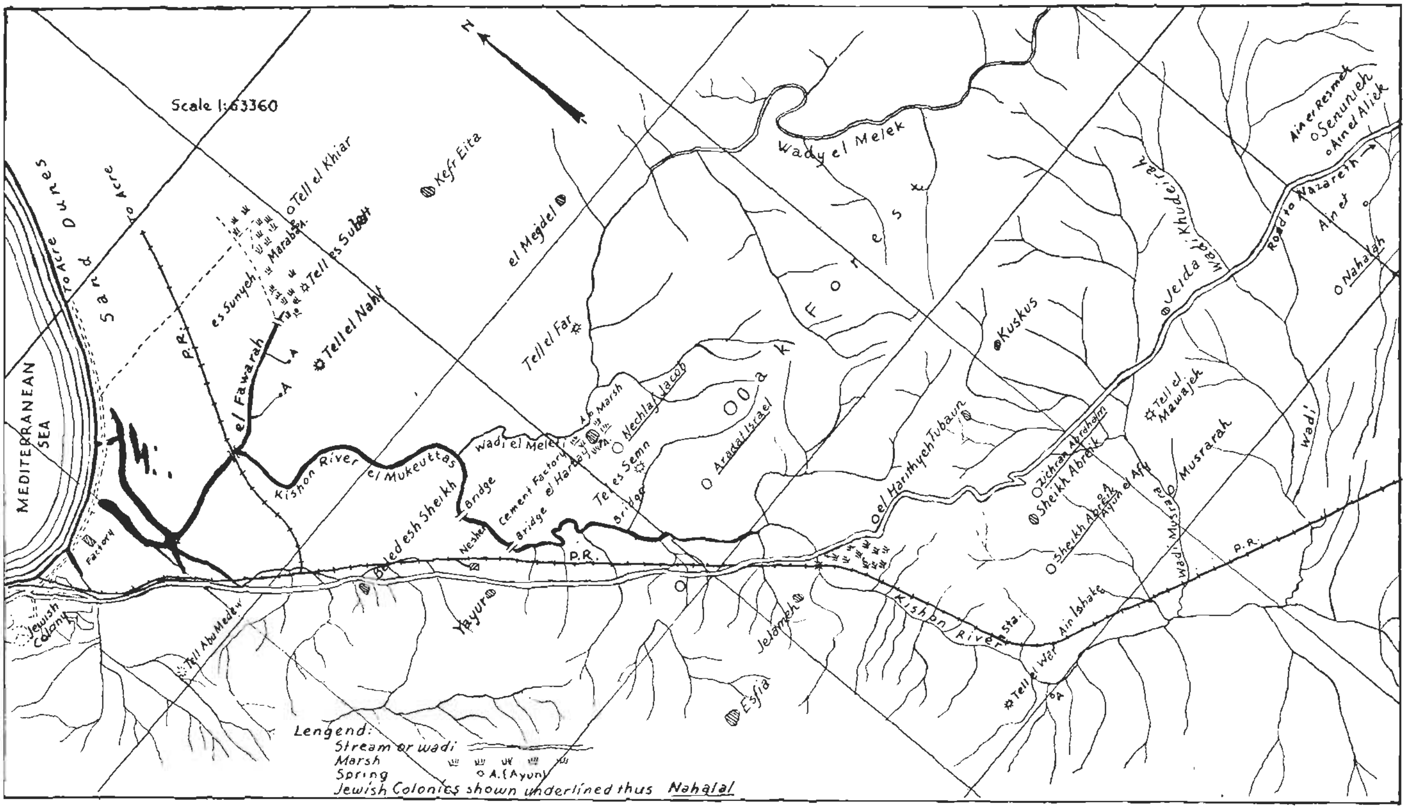
River. The second plain lies between the base of the Carmel and the Galilee ranges and extends eastward to the Plain of Jenin on the southeast and Mount Tabor on the northeast. This area is drained by the Kishon River emptying into the Mediterranean, and constitutes the central portion of the Valley of Esdraelon. East of this, from the main watershed to the Beisan Plain and the Jordan, is the Valley of Jezreel. This plain is drained by the Jaloud River, which runs due east and empties into the Jordan.

The Kishon is one of the most interesting rivers in Palestine. It has a large stream bed with deeply eroded banks flowing full during the winter. By the end of June, however, the river is dry, as are many of its important feeders, but the dry river bed is dotted with numerous pools varying in size and from 50 to 400 meters apart. Most of these pools are quite deep, remain wet the entire summer, and constitute a most serious source of anopheles and malaria. From a point about 5 miles from its mouth to the outlet, the bed of the river is at or below sea-level, and after the winter flow ceases, the water is uniformly saline in character despite the large perennial inflow of water from Ein Saadi.

The mouth of the Kishon is shallow and constricted, and is often blocked by a sandbar. This dams the stream, and causes the water to back up often to a point 10 kilometers from the sea. When the mouth is opened by the fishermen, the water again falls to its normal level. The mouth of the river shifts constantly to the north as a result of the sand drift, a feature characteristic of all the streams along the Coastal Plain.

From the malaria standpoint, the Kishon presents some interesting features. In the lower portion of the river the banks are free from vegetation (undoubtedly because of the high salinity of the water), and no anopheles-breeding has ever been noted by us—not even *M. multicolor*, which breeds in highly saline water. Beyond the nine-kilometer point, the whole river is overgrown with reeds and oleanders, the pools are covered with potamogeton and ranunculi, and one finds *A. elutus*, *A. hyrcanus*, and *A. algeriensis* breeding prolifically. In the marshes along the banks of the river caused by the springs from the base of Mount Carmel, *M. sergenti*, *A. elutus*, and *A. hyrcanus* breed freely and abundantly. Similar conditions

MAP VI



Kishon Area

Showing Streams, Wadis, Springs, and Marshes

prevail in the tributaries of the Kishon, and in the upper portion of the river itself.

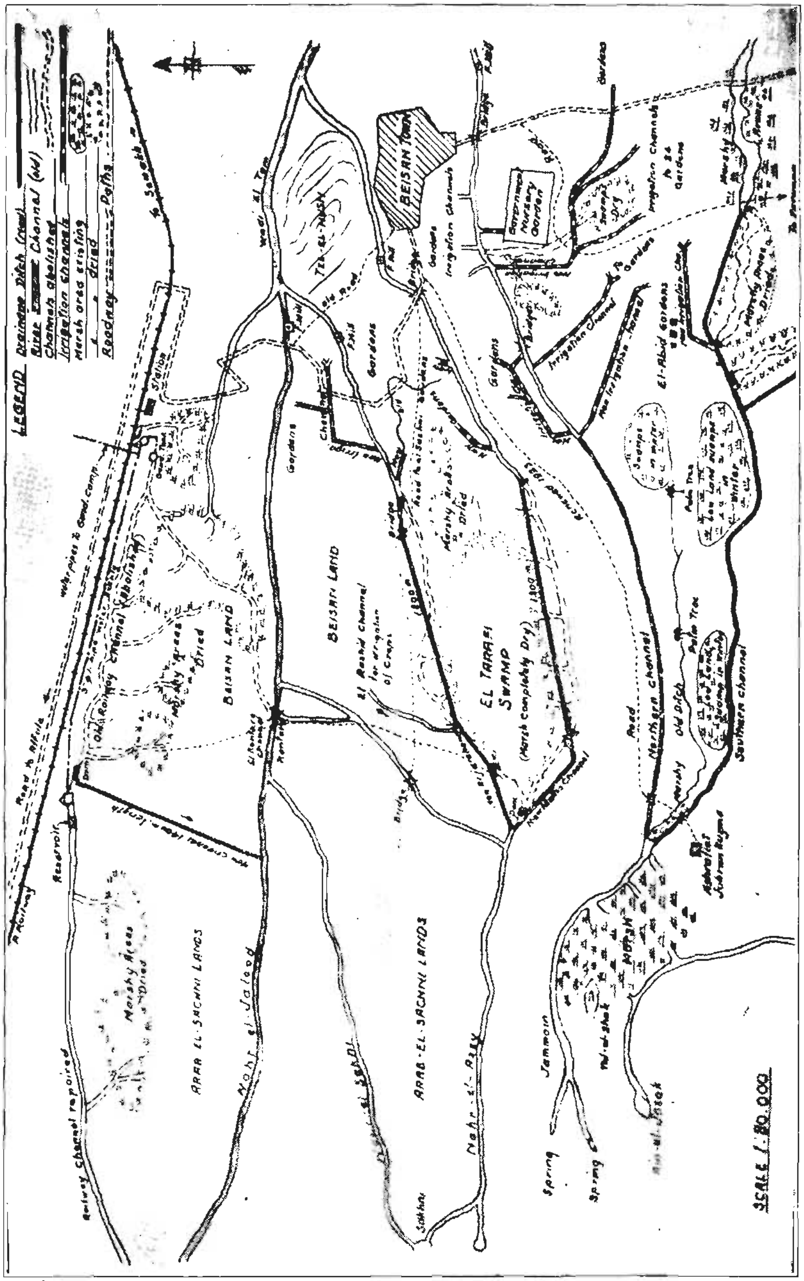
The abundance of springs and their surrounding marshes, together with the pools in the bed of the Kishon, account for the high prevalence of malaria in this valley. The whole of the Plain of Esdraelon was until recently one of the most malarious sections of Palestine, a fact indicated by the table (Table X) of blood and spleen examinations in the villages situated along the Kishon or its tributary wadis.

The Plain of Jezreel differs in many respects from the western portion of the plain. It is a narrow valley lying between the Gilboa and the Nebi Duhi ranges and extending from the Afuleh-Jenin road to the Jordan. In its short course of 12 miles it falls from about 35 feet above sea-level at Afuleh to 400 feet below at Beisan. It is drained by the Jaloud River, which has almost a straight easterly flow and is fed by large springs mostly on the southern side of the valley. The river has a rapid perennial flow, and should normally not be favorable for mosquito-breeding. Its rapid fall, however, rendered it suitable for mills, and many of them with their resulting marshes dotted the stream. Although only one of these mills is still in operation at present, the swamps caused by the ruined mills have remained. In addition to this, the abundant waters flowing out of the springs were only partially utilized and that in a most primitive fashion, the rest being allowed to form swamps. The common anopheles in this region were *M. sergenti* and *M. superpictus*, but there also were many places where the stagnant marsh bred *A. elutus*, *A. hyrcanus*, and *A. algeriensis* in abundance.

The Beisan Valley extends southward and eastward from the Jaloud River to Wadi Malih. It is bounded on the south by Mount Gilboa. Near Beisan these hills turn southward, thus also forming the western boundary of the plain. Here the plain is from 6 to 7 miles wide, but it tapers rapidly to about three miles at the southern point.

The chief sources of trouble in this area are the extensive but crude irrigation systems. These consist in the tapping of the nearest water supply with a shallow open ditch leading into a network of shallow irrigation ditches until the adjacent fields become water-

MAP VII



Swamp Area, Beisan, and Proposed Drainage Canals

logged. The surplus water is allowed to remain in shallow pools, which become covered with thick growths of marsh vegetation.

A fairly extensive entomological survey of this area has been made by Buxton. He reports the breeding of *A. algeriensis* and

TABLE X

Blood and Spleen Indices (Children under Thirteen) in Villages in the Valley of Esdraelon

	Location	Blood Index Per Cent	Spleen Index Per Cent	Source of Anopheles
Kishon Plain, Near Haifa:				
Gidru (1925)*.......	Acre Plain,	27.3	60.4	Deir el Beda, Fuara
Yazur (1924)........	foot of Carmel, east of Haifa	9.6	63.3	Kishon
Harbaj (1925).......	North side of Kishon, near Wadi Malik	16.5	66.6	Harbaj, W. Malik, Kishon
Sheikh Abreik (1925).	Near Kishon on north side	25.0	60.0	Kishon
Tel Shemam (1925)..	Near Kishon, in middle plain	16.3	......	Kishon
El Afuleh (1922).....	End of middle plain, near watershed of Kishon	11.3	63.6	W. Muweili
Zerain Plain:				
Merhavia (1922).....	Headwater of Zerain	9.8	12.5	W. Solim
Solim (1923)........	Headwater of Zerain	44.9	51.7	W. Solim, tributary of N. Jaloud
Nuris (1921)........	Near origin of Jaloud River	23.1	97.0	N. Jaloud
Tel Fir (1922).......	Near Jaloud	23.2	78.8	N. Jaloud
Beisan Plain:				
Beisan, town (Buxton, February, 1922)...	In Beisan Plain	26.0	33.0	Irrigation canals
Beni Saker, tribe (June, 1922)......	Nomads, living in the plain in summer and Jordan Valley in winter	0.0	64.0	....
Sakhne (1925).......	Bedouin camp near Ein Sakhne	27.0	82.2	Ein Sakhne
Tel es Shok (1922)...	Village near Ein Jemain	4.0	50.0	....

*Number in parenthesis signifies year when examinations were carried out; as a rule the year before control was started.

A. hyrcanus, the latter in greater abundance. He found adults of *A. elutus* without finding the larvae. Breeding of *M. sergenti* and *M. superpictus* was rare. We have found abundant breeding of *M. sergenti* near Tel es Shok, in the Ein el Asi, in the railway ditch near the station, and in a marsh near the Jaloud.

The Plain of Esdraelon was until recently, and in some portions still is, one of the most malarious sections of Palestine. From the coast to the Jordan there was an endless belt of malaria, and the marshes responsible for this condition were due either to human carelessness or to neglect. There are no natural swamps in the plain. The breeding-places were produced by the numerous springs, the water of which was either allowed to go to waste and to spread out in overgrown marshes or was used in primitive irrigation ditches with the same results. Table X, showing results of examinations in widely scattered villages throughout the plain, will give some idea of the ravages caused by this disease.

GALILEE

The natural boundaries of Galilee are the Plain of Esdraelon on the south, the Mediterranean on the west, the Jordan on the east, and to the north the gorge in which lies the lower valley of the Litany. By the Treaty of Versailles the present political boundary of Palestine runs from Ras el Nakura across the hills to the plain of Banias, the headwaters of the Jordan, and then continues along the outer margin of the plain east of the Sea of Merom (Lake Huleh), the Sea of Galilee, and the Jordan River.

The Galilee district includes a variety of country. To the west is the Coastal Plain extending from Acre to Ras el Nakura. To the east are the fertile plains of the Jordan and its headwaters. Between are a series of mountains interspersed by plateaus. The mountain region is divided into two parts, northern and southern, known as Upper and Lower Galilee, respectively. The hills of Lower Galilee are low and easily accessible, with many wide plains among them. The hills of Upper Galilee are high (from 2,000 to 4,000 feet) and steep, and are separated by deep gorges. The Wadi Halzun forms practically a natural dividing line between Upper and Lower Galilee, running roughly from east to west and traversing the Plain of Acre. These hills rise slowly from the Valley of Esdraelon, and really constitute the lower ranges of the Lebanon from which a large part of the waters of the Jordan are derived.

Lower Galilee.– The hills of Lower Galilee are divided into a succession of four parallel ranges running from east to west, with

broad plains between them. The southernmost range is the Jebel Duhi, or Little Hermon, lying between the Jaloud River and Wadi el Bireh, both of which fall into the Jordan. The steepest portion is Nebi Duhi at the northwestern part of the range. Beyond that to south and southeast are a series of plateaus intersected by the winding Wadi Dabu, known also lower down as Yeblah and Eshesh. The Kaukab section of this plateau has an abundance of springs.

The Nazareth range has at its southern border the Valley of Esdraelon and further east the Wadi esh Sherar (the upper part of Wadi Bireh). Its northern limit is defined by Wadi Malik, running westward into the Kishon and Wadi Fejaz, flowing eastward and emptying into the Jordan. This range is also interspersed with a series of fertile plains, particularly on the eastern portion of the range, draining chiefly into Wadi Fejaz.

The Jordan range lies between the upper part of Wadi el Malik and Wadi Fejaz on the south and Jebel Nirmin and Hattin on the north. It runs almost parallel to the Nazareth range.

The fourth of these ranges, known as the Shaghur range, extends from the Acre Plain to the Sea of Galilee. Its southern limit is defined by Wadi el Malik on the west of the watershed and Wadi Hamam, emptying into the Sea of Galilee, east of the watershed. The northern limit is defined by Wadi Halzun to the watershed and thence to the Sea of Galilee.

These ranges, as indicated above, are drained on the western slopes by Wadi Malik and Wadi Halzun, tributaries of the Kishon and Namein rivers, respectively; and on the eastern by the tributaries of the Jordan—Wadis Eshesh, Bireh, Fejaz, Hamam, Rabadiyeh, and Ahmud.

These wadis, as well as the marshes caused by the mills and the irrigation canals, which were led off from them, render this area one of the most malarious in Palestine. *M. superpictus* and *M. sergenti* breed in abundance, and *A. elutus* is common and widespread. The prevalence of malaria in this region is indicated by the data presented in Table XI.

Upper Galilee.—Upper Galilee consists of a quadrangle of hill ranges enclosing a high, fertile plateau. The southern range commences a few miles east of Acre, and runs eastward for about 25

miles. Its highest peaks are Nebi Heidar (3,440 feet), Jebel el Ares (3,520 feet), on which Safad is located, and Jebel Canaan (2,761 feet). From Jebel Canaan the hills descend rather sharply on the east to the Valley of Merom and the Jordan. The southern boundary of the eastern side of the range is Wadi Ahmud and on the western Wadi Halzun, by both of which it is drained. Extending northward from Jebel Canaan is the so-called eastern range, with the peaks Jebel Gahabiyeh (2,806 feet), Jebel Hunin (2,951 feet), and Nebi Aweideh (2,814 feet). This range descends precipitously to the upper Jordan and the Huleh Plain. On the western side another range runs northward, sloping gently to the Mediterranean coast, the southern part ending in the Plain of Acre, and the northern in the Plain of Tyre. At the northern end of this range there is the fourth range striking eastward and running parallel with the Kasimiyeh River to Jebel Hunin. This range is intersected by Wadi Seluquiyeh, which runs into the Kasimiyeh. Within this quadrangle is the high plateau of Upper Galilee with two peaks—the highest in the region—Jebel el Jermak (3,934 feet), near Safad, and Jebel Adather (3,300 feet). On this plateau are a number of fertile plains, notably those of Meirum and Yarun northeast and the Valley of Wadi el Karm southwest of the Jermak range.

TABLE XI

BLOOD AND SPLEEN INDICES IN VILLAGE NEAR THE WATER COURSES OF LOWER GALILEE

Village	Location	Blood Index	Spleen Index
Beth Gan	W. Sarona, branch of W. Fejaz	4.0	20.0
Yabniel (1923)	W. Madua, branch of W. Fejaz	3.0	36.5
Yemenites	W. Madua, branch of W. Fejaz	3.6	38.4
Mejdel	W. Hamam	7.1	75.0
Migdal	W. Hamam and W. Rabadiyeh	2.6	27.4
Bedouins, Migdal	W. Rabadiyeh	4.3	54.3

On the western slopes, the ranges of Upper Galilee are drained partly by Wadi Halzun, the dividing line between Upper and Lower Galilee, and partly by the wadis to the north of Nahr Mefshukh: Wadi el Karm, Wadi Kerkereh, Wadi el Ezziyeh, and Wadi el Hubeishiyeh. On the eastern slope are the Wadis Ahmud, Wakas, and Hindaj. On the north side running into Kasimiyeh are Wadi el Hajeir with its long tributary Wadi Seluquiyeh.

The Galilees have a higher average rainfall than either Samaria or Judea. In the higher plateaus north of Wadi Malik, there are but few springs and the water supply is obtained chiefly from wells and cisterns near the villages. There are, of course, rare exceptions as is the case in Safad, in the Ahmud Basin, which has several springs in the neighborhood. Similarly Wadi Farah, the upper part of Wadi Hindaj, has a permanent stream fed by Ein el Balat and Nebi Auba.

In the foothills, on the other hand, particularly in Lower Galilee, there are numerous springs. On the eastern side of the town of Nazareth, the villages Seffurieh, Hattin, Ferradiyeh, and others have abundant spring supplies. The same is true of Yabniel, Beth Gan, Bethania, Migdal, Rosh Pina, and Ayeleth. On the western slope there are the copious Kabri springs which supply Acre and its vicinity with water.

FIG. 10.—Wadi Wakas, a typical foothill stream in Upper Galilee.

All the wadis in Lower Galilee carry perennial streams. In Upper Galilee the streams on the eastern slope are all dry during the summer except those sections fed by springs (Wakas, Ahmud), while all those on the western slope have a perennial flow. Wadi Mefshukh derives its water from the Kabri springs; Wadi Karm receives its flow from the large springs Ras en Neba; Wadi Ezziyeh also has a perennial stream.

Of the system of wadis in this area we have studied Wadi Ahmud in the Plain of Gennesareth and Wadi Hindaj and Wakas in the Ardhel Kheit, near the Sea of Merom. Wadi Ahmud is dry in the summer in this region, and is not of serious moment. Wadi Hindaj also dries fairly early except in years of exceptionally high rainfall, and is a source of trouble particularly in June, when it breeds *M. su-*

perpictus. Wadi Wakas, on the other hand, has sections fed by springs which carry water all year. Being the only water-carrying wadi, all the cattle in the neighborhood are brought there. Consequently, control is very difficult, and *M. superpictus* and *M. sergenti* breed there prolifically, the former during the spring and summer, and the latter during the later summer and fall. This, in addition to the proximity of the Huleh marshes, which will be described later, causes the plain to be highly malarious.

JORDAN VALLEY

The Valley of the Jordan or Ghor is a rift produced by an earth movement which left a deep, moderately wide gorge thousands of feet below the plateaus on either side. This gorge falls 2,372 feet in about 104 miles by a uniform though varying gradient. Above Beisan the Jordan runs in an inner narrower ravine, called the Zor. The Zor is between one and two miles in width, is very fertile and is covered with vegetation. The Ghor rises sharply, at points as much as 200 feet above the Zor, and varies in width as well as fertility in different places. In the Huleh Plain it is 20 miles long and 5 miles wide, the upper part very fertile and well watered, the lower part a large marsh. Below Lake Huleh, the plain narrows to a few hundred yards, and the river runs in a deep basalt gorge. At the head of the Sea of Galilee it widens again to about 8 miles, occupied mostly by the lake and partly by small plains on either side. South of the Sea of Galilee it narrows again to 3 or 4 miles until south of Jissr, where it begins to widen again, merging into the broad Plain of Beisan. Below the Plain of Beisan, it becomes once more very narrow and then gradually widens again to an average width of 3 miles down as far as Ras Umm Kharrubeh, where it begins to expand, reaching its maximum width between Jericho and the Dead Sea.

This valley is drained by the Jordan River and its tributaries. The source of the Jordan is at the base of Mount Hermon. It has three main branches. The central tributary is Nahr Hasbani which drains the valley between Mount Hermon and Jebel ed Dhahr. The chief source of the Hasbani is a large spring, Nebi Hasbani, at the foot of Ras-el-Auja. Below the Hasbeya dam the river runs southward, at first in a shallow channel and then, below Khan es-Suk, in

a deep bed. Below the Khan it is fed by a number of large springs, and consequently issues into the plain as a good-sized stream.

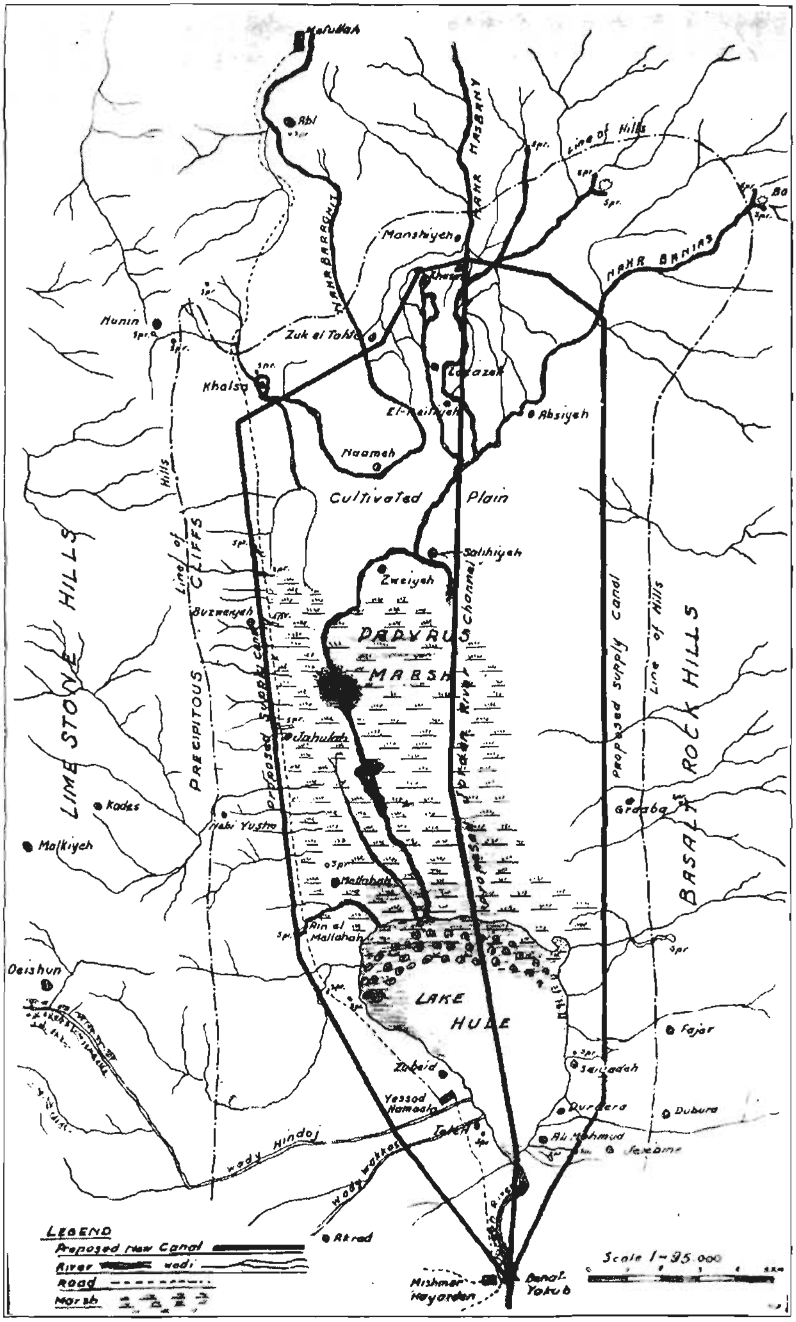
About five miles below Tel el Kadhi, it unites with two other tributaries of the Jordan, Wadi Leddan and Wadi Banias. These two wadis constitute the real sources of the Jordan, and carry a large amount of water. Wadi Leddan has its source in a large spring issuing from the western side of Tel el Kadhi, and Wadi Banias originates in the historic Cave of Pan. The two streams join just before

FIG. 11.—A view of the Jordan River near Betania

falling into the Hasbani, and carry several times as large a volume of water as the latter. The united stream now runs directly southward across the Plain of Huleh, and as the bed is insufficient it spreads out in the well-known Huleh Marsh.

The Huleh Marsh is estimated to be about 6 miles long and $1\frac{1}{2}$ miles wide. On the east side it lies right against the hills, but on the west, a narrow plain from 1 to 2 miles wide rises slowly toward the hills. The marsh is overgrown with huge solid masses of reeds and papyrus, and is practically inaccessible. On both sides of the Huleh Plain there are numerous springs. Part of the water is used for irrigation while the rest serves to augment the marsh area.

MAP VIII



HULEH AREA

Below the marsh is the shallow muddy Sea of Merom (Lake Huleh). It is about 4 miles long and 3 wide. On the west of the lake is a small plain which slopes upward to the hills, and is drained by several wadis which fall into the lake.

The real Jordan issues from the southern end of the Sea of Merom. Here the stream is about 60 to 80 feet wide, and has a rapid flow. Its banks are badly overgrown with reeds and oleanders, and in many places it is covered with aquatic vegetation. Below Jissr Banat Yakub, the stream runs in a gorge, falling very sharply (700 feet in about 8 miles) until it reaches El Batihah, a marshy plain at the head of the Sea of Galilee. The Jordan issues again from the southwestern end of the Sea of Galilee, and follows a general southerly direction, bending, winding, often almost doubling on itself. At many of the sharp bends it overflows the banks and causes serious marshes. In the center, the current is usually very rapid, but its speed varies with the width of the stream, which ranges along the course from 50 to 180 yards.

The river is in flood during the rains and when the snow melts on the Hermon, reaching the maximum in April. Beginning in May and continuing throughout the summer, it falls rapidly, reaching its minimum level in September. In flood time it is a raging torrent exceedingly difficult and unsafe to cross; but during its low period it can easily be crossed by wagon or on foot at many points, where the depth is only 2 or 3 feet. The average fall in depth between high and low level is about 4 feet. Both phases offer peculiar problems in malaria control which will be discussed more fully later. At high level the flooded areas and the resulting marshes breed *A. elutus*. At low level the gravel bed is exposed in many places, and excellent breeding-places are thus provided for M. *sergenti*, which is very abundant during September.

A large number of tributary wadis fall into the Jordan on either side. The largest perennial affluents drain the eastern ranges. The important eastern tributaries from north to south are: (1) the Wadi es Semakh, which falls into the Sea of Galilee; (2) the river Yarmuk, the largest affluent, which falls into the Jordan near Jissr el Mejame; (3) Wadi el Arab, and (4) Nahr es Zerka, the second largest affluent. Between these main streams there are many springs which fall directly from the slopes of the mountains to the river.

On the western or Palestinian side, the most important affluents are Wadi Rabadiyeh and Wadi Hamam, which fall into the Sea of Galilee; Wadi Fejaz, emptying into the Jordan about 2 miles south of the lake; Wadi el Bireh, which falls into the Jordan opposite Wadi el Arab, south of Jissr el Mejame; the Nahr Jaloud, which joins the Jordan north of Beisan, and Wadi Farah, draining the highlands of Samaria.

From the standpoint of malaria, the entire Jordan Valley is, undoubtedly, the worst in Palestine. There exists here a combination of all the varieties of breeding-places for the local anopheles. There is an abundance of *A. elutus*, *M. sergenti*, and *M. superpictus*.

TABLE XII

BLOOD AND SPLEEN INDICES IN VILLAGES IN THE HULEH PLAIN, UPPER GALILEE

Village	Location	Blood Index	Spleen Index
Mishmar (1923)	Upper Jordan	3.4	53.1
Yessod (1923)	Sea of Merom	5.3	21.5
(1927)		12.2	28.5
Tlell (1923)	Sea of Merom	22.2	100.0
(1927)		16.7	95.8
Usbed (1923)	Sea of Merom	14.8	55.2
(1927)		7.0	66.0
Malaha (1927)	Sea of Merom	37.5	72.5
Almanieh (1927)	Sea of Merom	20.0	95.0
Ayeleth (1927)	W. Wakas 3½ kilometers from Huleh	0.0	30.0
Mahanaim (1927)	6 kilometers from L. Huleh	0.0	6.2

A. elutus breeds along the entire course of the stream. Along the banks of the Jordan and the streams which constitute its headwaters there are many stagnant marshes which favor the breeding of this species as do the mass of ranunculi or potamogeton with which the stream is covered in many places. Finally, there are the Huleh Marshes at the head of the Jordan in which *A. elutus* breeds in great abundance, rendering practially the whole plain uninhabitable.

M. sergenti and *M. superpictus* breed profusely in the gravelly, precipitous springs and wadis which arise on the hills on either side of the stream and flow swiftly as winding, shallow, overgrown streams into the Jordan. In addition, the exposed river bed when the stream is low during August and September also becomes a fertile breeding-ground for these two species of anopheles.

Because of its sparse population of almost wholly nomadic Bedouins, we have given little attention to the part of the Ghor below Beisan. But for more than three years we have studied intensively the conditions in the upper part of the Jordan, above the Huleh Marsh, in the vicinity of the Sea of Merom and the Huleh, and in the Plain of Gennesareth; as well as in the part between the Sea of Galilee and Jissr el Mejame. The extent of the prevalence of malaria in these regions is clearly illustrated by the table of spleen and blood rates (Table XII). It is evident that before control was started the malaria prevalence in this region was the same as, if not greater than, that in the Valley of Esdraelon and in the districts directly affected by the Coastal Marshes.

CHAPTER IV

BIONOMICS OF THE ANOPHELES OF PALESTINE

TYPES OF ANOPHELES

Eight different species of anopheles have been found in Palestine. One of these is almost exclusively an urban dweller, breeding in cisterns, the others are rural, marsh-breeding mosquitoes. Four species belong to the genus *Anopheles*, and four are *Myzomia*.

A. bifurcatus.—Contrary to its habits in other parts of the world, this species of anopheles breeds here only in cisterns. A doubt has been raised as to whether the local type corresponds to the form breeding outdoors in Europe. A careful comparison has established the fact that the larvae and imagos are identical with those found in Italy. Yet the difference in the breeding habits of the Palestinian and the European forms and the fact that the local mosquito is an important malaria vector, the sole vector in the highland cities relying on cisterns for their water supply, have led some to the conclusion that functionally, if not morphologically, the Palestinian form is a distinct variety, or even a distinct species. This view seems untenable. The Palestinian *A. bifurcatus* appears in every way identical with the European variety. In Palestine it finds the optimal conditions of temperature and shade in the house cisterns where it breeds throughout the year. Like the *Stegomyia* it is here a house-breeding mosquito, and it is probably this accident of cohabitation with man that has rendered it an important vector of plasmodia. In Europe it breeds out of doors during the colder seasons of the year and, consequently, plays an insignificant rôle in the transmission of malaria. This is a striking example of the relation of peculiar local environmental conditions to the epidemiology of malaria.

The local *A. bifurcatus* is a medium-sized grayish mosquito. The wings are not spotted. The thorax is covered with bright hair which gives the appearance of a white median rib. It breeds here principally in cisterns and in the cemented inlets to cisterns. Outdoors it has been found only once by Buxton in the marshes near

Birket Ramadan; and once we have found the skin of a larva in the upper part of Wadi Hindaj. Larvae may be taken in cisterns at all seasons. Our observations indicate that because of the uniform temperature prevailing throughout the year, larval development does not cease during the winter. Temperatures of cisterns in Haifa during December and January ranged between 18° and 20° C. At this temperature in the laboratory the period of development from egg to adult is from twenty-seven to thirty days. Adults are not commonly seen during the winter months, but imagos were caught twice, once in Artuf in the foothills, and once in Jerusalem; both catches were made during the month of February.

A. algeriensis.—This mosquito resembles *A. bifurcatus*, but is uniformly grayish-brown in color, has black instead of white hair ón the thorax, and is much smaller. It is an outdoor, marsh mosquito, breeding in stagnant overgrown marshes, usually associated with *A. hyrcanus.* It breeds more actively during the winter and spring months than during the summer. It is evidently a marsh-dweller, for we have never found it in houses, stables, or tents. For this reason, and because its active breeding season does not correspond with the malaria season, it need not be considered a serious vector of malaria parasites.

A. hyrcanus (*sinensis*).—This is a very large, active mosquito. Its wings have three long black spots on the costal border formed by black scales. The palpi are somewhat shorter than the proboscis, and are covered with two bands of white scales. The legs are black with narrow white bands. It breeds in the same type of marsh as *A. algeriensis* and, like it, is a marsh-dweller. It also breeds during the winter, but its active period extends into the summer. Larvae are readily found from November to July. It is a vicious biter out in the field, but specimens have never been found in houses, stables, or tents. Once a specimen entered a passing railway-car, and was taken while attempting to bite. Because of its localized habitat, we do not consider it a carrier of any importance. Only a few dissections have been made, and while these have been negative, the number of specimens was too small to warrant any conclusion.

A. elutus.—This species resembles very closely *A. maculipennis* in its morphology and breeding habits. It is a large, dark mosquito,

and has four black dots on the wings caused by the crowding of scales at the branching of the veins. The palpi and legs are uniform in color. It breeds in stagnant water of any description provided it is not foul; it is usually found among algae, chara, potamogeton, or ranunculi. Its breeding season extends from the end of March to the end of November, but it is most active during May, June, and July, and the latter part of October and November. It is a house-visitor, and is without doubt the most important carrier of malaria in Palestine.

Among the *Myzomia*, there are three species which breed locally, while one, *M. pharoensis*, can only be considered an occasional visitor from Egypt. During some years no specimens were encountered; during others, small numbers were found in various parts of the country. In 1927 active breeding was found in the Huleh Marshes and in Birket Ramadan.

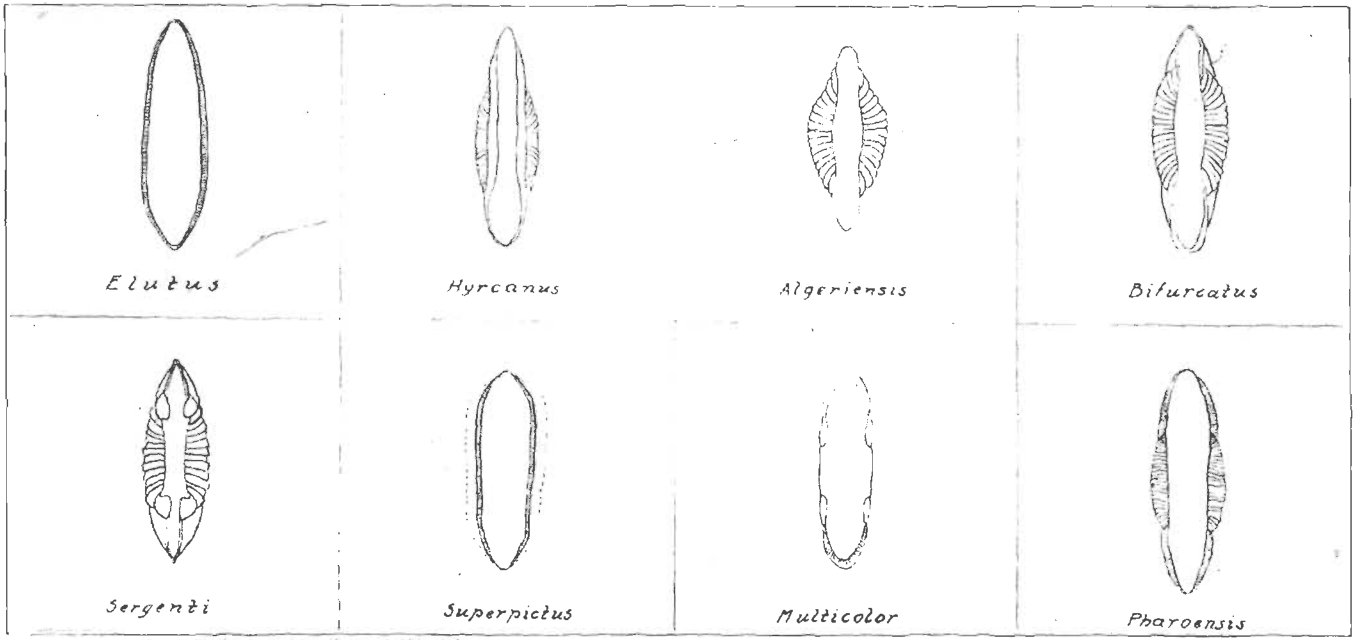
M. pharoensis.—This mosquito resembles *A. hyrcanus* in some respects. It is a large, yellowish mosquito. The palpi are very scaly, with mixed white and gray scales and alternating white and brown rings; the last segment is white. It has two black spots on the thorax and four black spots on the border of the wings. On account of its rare occurrence and localization (Huleh, Ramadan only) it cannot be considered an important vector in Palestine.

M. sergenti, M. superpictus, and *M. multicolor* greatly resemble one another. They are small, whitish-gray mosquitoes. The palpi are banded, white and black rings alternating. They have four black bands on the costal border of the wings.

The imagos of these three species differ from one another chiefly in the width of the white and black bands on the palpi, particularly the last segment, and in the character of the hair or scales on the thorax. *M. sergenti* has yellowish hair on the thorax and a narrow white terminal band. *M. superpictus* has whitish scales on the thorax and a broad white terminal band on the palpi. *M. multicolor* has white scales like *superpictus,* but the terminal band on the palpi is narrow and black. It should be noted that one often encounters specimens of *M. superpictus* in which the terminal band has an admixture of black hair.

Biologically the three species differ a great deal more than they

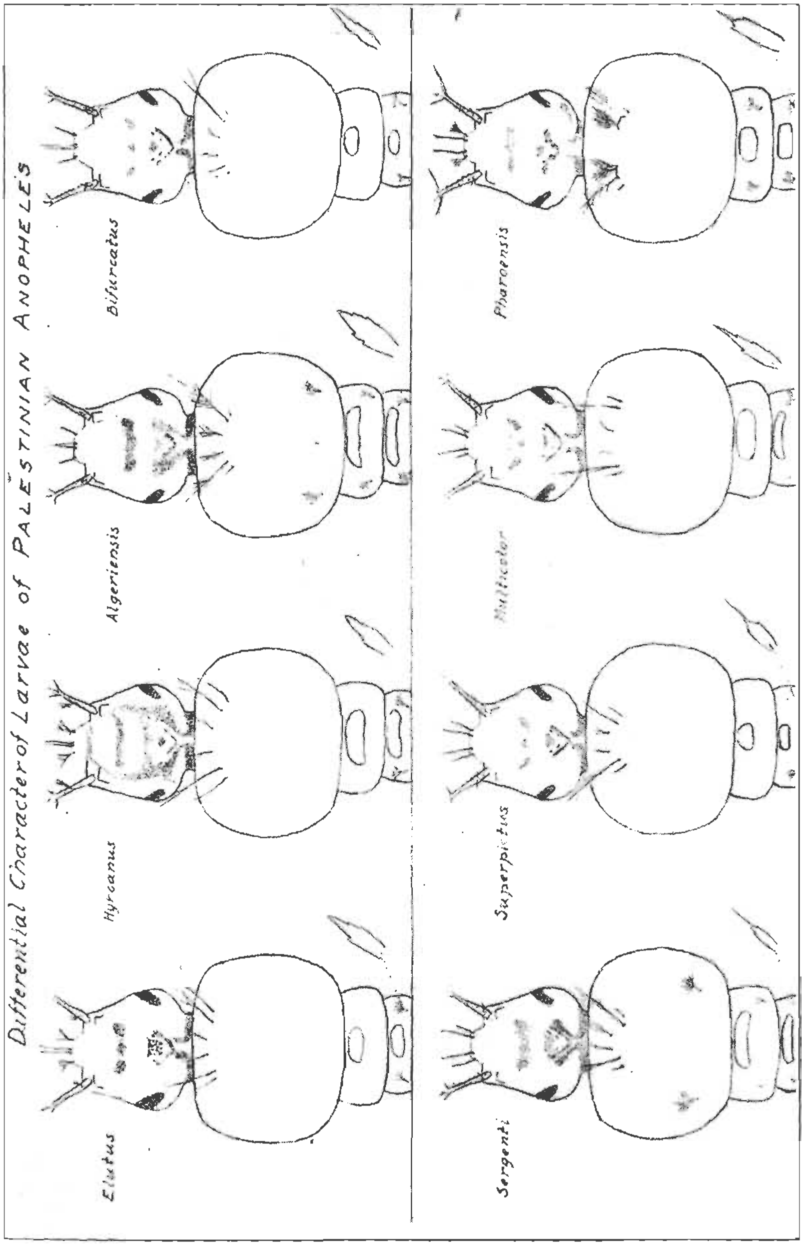
CHART I



Malaria Research Unit, Haifa, 25.2.1926. Drawn by M. Ashner.

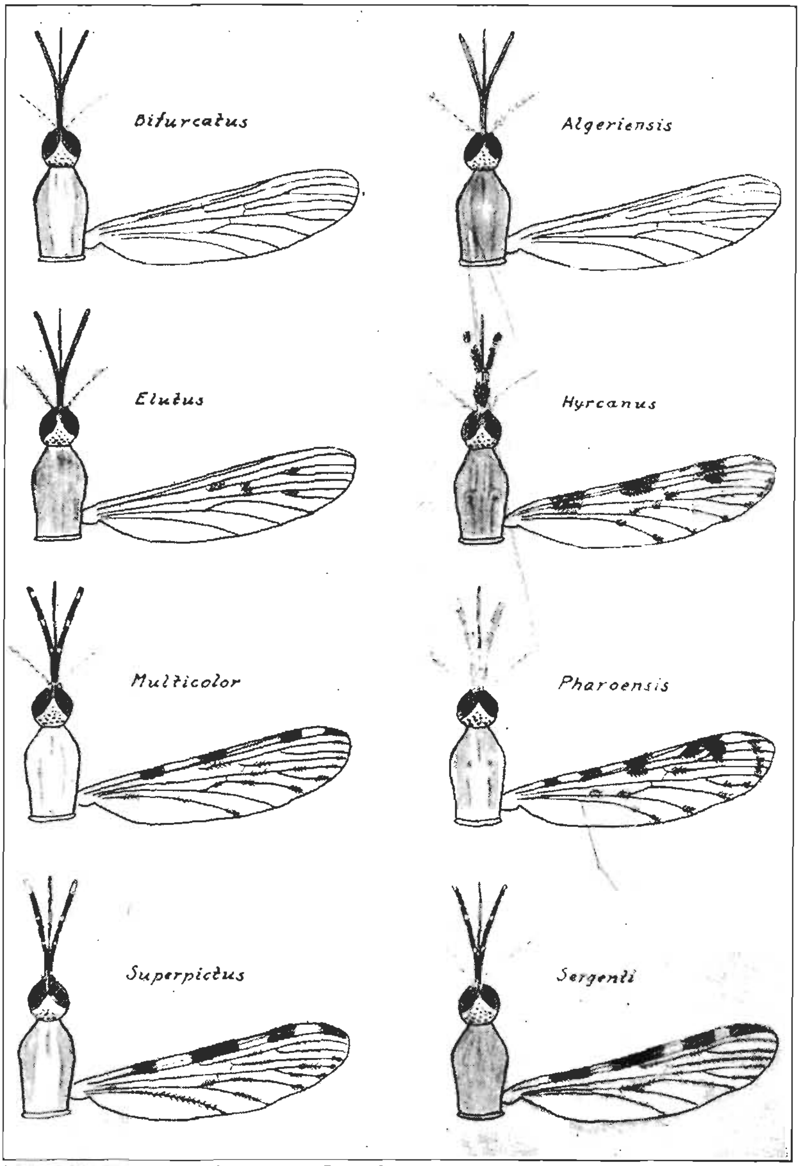
DIFFERENTIAL CHARACTER OF EGGS OF PALESTINIAN ANOPHELES

CHART II



Differential Character of Larvae of Palestinian Anopheles

CHART III



Malaria Research Unit, Haifa, 25.2.1926. Drawn by M. Ashner.

DIFFERENTIAL CHARACTER OF PALPI, THORAX, AND WINGS OF PALESTINIAN ANOPHELES

do morphologically. Both *sergenti* and *superpictus* breed in fresh flowing water, but the former prefers slowly moving water such as seepage, or semistagnant irrigation canals, while the latter breeds even in rapidly moving streams. The larvae of *sergenti* appear later than those of *superpictus*, and while active breeding of the former begins only in early September, the latter begins to breed in June, declines during August, and becomes active again in September. *M. superpictus* is apparently intermediate in its temperature requirements between *A. elutus* and *M. sergenti*. *M. multicolor* breeds in standing salt marshes of high salinity, and for this reason its distribution, unlike that of the other two species, is more closely confined to certain localities.

All three species are house-visitors. However, dissections and epidemiological evidence indicate that in Palestine only *M. sergenti* and *M. superpictus* are important malaria carriers.

Differentiation of the various species.—The accompanying keys, based on those prepared by Buxton, facilitate the identification of the adults and larvae of the local species. A still better guide are the accompanying drawings of the egg, the head of the larvae, and the thorax and wing of the imagos of the different species.

KEY TO THE FOURTH STAGE ANOPHELINE LARVAE OF PALESTINE
(MODIFIED ON BASIS OF KEY PREPARED BY BUXTON)

1. Shaft of antenna with branched hair 2
   Shaft of antenna with simple hair 5
2. Outer clypeal hair dendriform 3
   Outer clypeal hair simple or nearly so 4
3. Antennal hair branched at half the length of antenna and with about ten branches .... *hyrcanus*
   Antennal hair branched quarter length of antenna with about four branches .... *elutus*
4. Inner clypeal hair feathery
   Leaflets broad and deeply dentate
   Comb with about sixteen teeth .... *algeriensis*
   Inner clypeal hair smooth
   Leaflets long and slender
   Comb with about twenty-five teeth .... *bifurcatus*
5. Outer clypeal hair branched
   Inner clypeal hair feathery .... *pharoensis*
   Outer clypeal hair simple 6

6. Innermost shoulder hair much branched
Palmate hairs end with long hair 7
Innermost shoulder hair branched a little at tip
Palmate hair like elutus .... *multicolor*
7. Palmate hairs on segments 3–7 .... *superpictus* (*palestinensis*)
Palmate hairs on segments 1–7 .... *sergenti*

ANOPHELINE MOSQUITOES OF PALESTINE
(MODIFIED ON BASIS OF KEY PREPARED BY BUXTON)

1. Wings not spotted 8
Wings spotted 2
2. Spotted in middle of wing only .... *elutus*
Spotted along front edge also 3
3. Palpi thick and shaggy 4
Palpi slender 6
4. Palpi peppered brown and white .... *pharoensis*
Palpi banded distinctly 5
5. Hind tarsi dark except for very narrow white rings .... *hyrcanus*
Terminal joint only white .... *hyrcanus* (*var. pseudopictus*)
6. Tip of palpi black .... *multicolor*
Tip of palpi white 7
7. Tip of palpi broad white band, thorax scaly .... *superpictus* (*palestinensis*)
Tip not broader than the other white rings, thorax hairy .... *sergenti*
8. Large or medium size, pale hairs on thorax, sides of thorax darker than dorsum .... *bifurcatus*
Small; light brown hair on thorax; sides and dorsum uniform. *algeriensis*

FACTORS INFLUENCING ANOPHELES-BREEDING

Character of breeding-places.—The character of the swamp usually determines the type of mosquito which will breed there. This is at times so clear-cut that one can almost predict with certainty the type of anopheles from the nature of the breeding-place and vice versa. Stagnant open pools in winter wadis, stagnant water overgrown with ranunculi, wells and reservoirs overgrown with algae, invariably breed *A. elutus*. When the water is sheltered, badly overgrown, and covered by vertical vegetation, *A. hyrcanus* is the common mosquito, while *A. elutus is rarely* found. No sooner, however, is such a place cleared and exposed than the former species is almost

completely replaced by the latter. Islands of ranunculi in so rapid a stream as the Jordan form ideal breeding-places for *A. elutus*.

The partially stagnant swamps caused by overrunning irrigation ditches and streams breed *A. elutus* in the stagnant portions and *M. sergenti* in the moving water. In general, very slowly moving streams, such as open seepage-canals, sluggish parts of wadis, seepage under rocks and pebbles, etc., will almost invariably harbor *M. sergenti*. At times they may also be associated with *M. superpictus*. Steadily flowing streams emanating from springs may also breed both these species, but more often they harbor almost exclusively *M. superpictus*. Salt water, containing from 1 to 3 per cent salt, is the favorite breeding-place of *M. multicolor*. *A. bifurcatus* is exclusively a cistern-breeder, although as mentioned above, on rare occasions, it has been found breeding out of doors. *M. pharoensis* is rare in Palestine, but has been found breeding in the coastal swamps Ramadan and Kabbara, and in the Huleh marshes in places where *A. elutus* is usually found.

Salinity and reaction.—There is today a considerable amount of information concerning the relation of anopheline mosquitoes to malaria transmission, but there is a scarcity of data on the factors influencing the development of these mosquitoes. Such data are of more than theoretic interest, since a more detailed knowledge of the physicochemical factors influencing anopheline development must ultimately prove of considerable value in practical control. For this reason the observations made in our laboratory on the relation of such factors as temperature, salinity, reaction of the water, etc., on anopheline development, though far from exhaustive, will be given in some detail.

Effect of salinity.—In studying the effect of salt concentration on anopheles, it is necessary first to differentiate between species which breed in sweet or slightly brackish waters, and those which tolerate a fairly high degree of salinity. This is particularly important, because of the ambiguous statements often encountered in the literature referring to the breeding of anopheles in "brackish" waters, which are apt to be misleading.

There are, apparently, many species of anopheles which breed in water of high salinity. *M. multicolor*, found in Palestine (and also

Egypt), breeds in sea-water and salt-water basins having a salinity as high as 4 per cent. Other species have been reported from various parts of the world. Dutton reports that in Gambia *A. costalis* breeds in salt-water pools; Balfour found the same species in Kartoum in water having a salinity of about 2 per cent. De Vogel, working with larvae of *A. Rossi* (?), found that they tolerated 2.9 per cent of salt. Foley and Yvernault report *A. chaudoyei* (a synonym of *M. multicolor*) breeding freely in sea water at Algiers. Darling reports the breeding of *A. albimanus* in swamps containing 1.93 per cent salt. Griffiths found that *A. cruciens* was able to propagate in 50 per cent sea water, and was not affected unfavorably by a transfer to undiluted sea water. Other authors refer to the breeding of one or another species of anopheles in "brackish waters."

Our observations were confined to the fresh-water species. We attempted to determine whether the ordinary Palestinian fresh-water varieties known to be malaria vectors would tolerate saline waters and, if so, the degree of salinity they could support. This question was especially important to us from the standpoint of practical mosquito control.

Relation of salinity to egg-laying—These series of experiments were statistical in character. Full grown females with ripe ovaries were placed in mosquito cages, and saltcellars or watch glasses containing different concentrations of salt solutions or various sea-water dilutions were placed irregularly on the bottom of the cage. Every morning the glasses were removed, and the batches of eggs laid in each dish recorded. These observations were continued throughout the entire breeding season—May to October, inclusive.

The results are shown in Table XIII.

These results show conclusively that all three species of anopheline mosquitoes show a preference for fresh water or water of low salt content. In the salt solution experiments three-fifths and two-thirds of the total egg-layings of *A. elutus* and *M. sergenti*, respectively, were in fresh water. If the layings in fresh water and physiological salt solution are taken together, then the percentages of the total layings are: *A. elutus*, 77 per cent (fresh-water and high sea-water dilutions, 92 per cent); *M. sergenti*, 88.5 per cent, and *M. superpictus*, 78.8 per cent. It is apparent that these species are able to exercise

selection with regard to salinity of the water and show a definite preference for fresh water or water of low salinity, not greater than from 0.5 to 0.85 per cent.

Effect of salt concentration on hatching of eggs.—Another series of experiments dealt with the effect of various salt concentrations on the hatching of eggs. Different combinations always yielded the same results. In one series of experiments, the eggs were left in the solution in which they were laid, and the dish covered so as to prevent evaporation; in another series, eggs laid in fresh water were

TABLE XIII

EGG-LAYING BY ANOPHELINE MOSQUITOES IN WATERS OF DIFFERENT DEGREES OF SALINITY

Species of Mosquito	Total Layings	Layings in Fresh Water	Layings in Various Salt Solutions		
			M/8	M/4	M/2
A. elutus	126	76	21	16	13
M. sergenti	135	91	32	9	7
M. superpictus	33	13	13	4	3
			Sea-Water Dilutions in Distilled Water (Per Cent of Sea Water)		
		0	12½	25	100
A. elutus	37	10	13	11	3

transferred to different salt solutions; in a third series, eggs were transferred from M/8 saline solution to various salt solutions; in still another series, eggs laid in various salt solutions were transferred to fresh water.

The results varied only slightly. In the first series, practically all the eggs laid in fresh water or M/8 saline solution hatched in forty-eight hours, while none of the eggs laid in M/4 and M/2 salt solution hatched.

In the second series, the eggs were transferred immediately from fresh water to different salt concentrations. Those transferred to water or M/8 saline solution hatched in forty-eight hours, while of those placed in M/4 and M/2 solutions, only two or three eggs hatched in one experiment but the larvae died immediately. In the

same series, there were two experiments in which the egg transfer was made twenty-four hours after laying; in these experiments, all the eggs hatched at about the same time, but those in M/2 died at once, and those in M/4 died twenty-four hours after they were hatched.

In the third series, there were two sets of experiments with practically the same results. In M/2, none of the eggs hatched; in

TABLE XIV

EFFECT OF SALINITY ON HATCHING OF ANOPHELINE EGGS*

Type of Experiment	Number of Experiments	Fresh Water	Average Percentage of Eggs Hatched in Salt Solution		
			M/8	M/4	M/2
Eggs left in original solution....	5	All	All	0†	0†
Eggs transferred from fresh water to various salt solutions shortly after they were laid....	4	All	All	3 eggs in one experiment; larvae died at once	3 eggs in one experiment; larvae died at once
Eggs transferred from fresh water to salt solutions one day after they were laid....	2	All	All	All; larvae died at once	All; larvae died in 24 hours
Eggs transferred from M/8 to various salinities.......	2	All	All	50% in 1, 75% in 2; larvae dead in 24 hours	0†

* Eggs of *A. elutus*, *M. sergenti*, and *M. superpictus* were used in these experiments.
† *Eggs invariably blanched.*

M/4, from 50 to 75 per cent of the eggs hatched and the larvae died in twenty-four hours; on the other hand, those in M/8 and fresh water hatched and remained active.

In the last series (from various salinities to fresh water), the results were the same as in the first.

The results are briefly summarized in Table XIV. It is apparent that salinities of M/4 or higher have a deleterious effect on the eggs and young larvae of the anopheles studied. This effect is readily seen with the naked eye and under the microscope. To the naked eye the eggs appear blanched, and when examined under low power, they are seen to be swollen and distorted, and occasionally the egg

wall is burst. Eggs kept in fresh water long enough to harden the chorion are not affected by the high salinity in so far as hatching is concerned, but the young larvae die shortly after they are hatched. On the other hand, eggs laid directly in high salt concentrations are immediately affected by the salinity and none of them hatches.

Effect of salinity and reaction on the development of anopheline larvae.—Experiments also were made to determine the effect of the combined factors, salinity and reaction of the water, on the development of young larvae. Many experiments were performed under various conditions.

The results were not always uniform because of the difficulty in controlling all the variables. One of the difficulties encountered was the maintenance of a constant reaction in the various salt concentrations as well as in ordinary water. The tendency was for the solutions to become progressively alkaline. To obviate this difficulty small amounts of phosphate solution were used as a buffer (5 cc. M/15 solution to 45 cc. water or saline solution), and the desired indicator added directly to the water or salt solution. This enabled us to follow the changes from day to day and make the necessary corrections, thus keeping the reaction fairly constant.

Even with these precautions the variables are too numerous to give uniform results. If one succeeds in keeping the reaction and salt concentration constant, there are still variations due to salt effect, food supply, and bacterial growth, which are difficult to regulate. Nevertheless, an analysis of the large number of experiments indicates that certain effects are fairly uniform and constant.

In ordinary tap or distilled water, buffered and adjusted to various reactions, the reaction has a decided effect on young larvae. They grow more rapidly, and are more active in slightly acid than in alkaline solutions. The optimum reaction for *A. elutus* appears to be pH 6.6. The stimulating effect noted in acid solutions was only temporary in character (at least under the conditions of the experiments) and, after a week or so, there was a tendency toward equalization, when the larvae in the more alkaline solutions developed at the same rate as those in the acid media.

In salt solutions, the results are more variable, but essentially of the same character, the effect of the reaction being somewhat ac-

centuated. In salt concentrations higher than M/4, the larvae die promptly whatever the reaction. In salt concentrations lower than M/8, the reaction of the substrate apparently plays a significant rôle, varying with the salt concentration. In alkaline solutions (pH 8.0) the larvae are distinctly smaller and less active than in the acid, and they survive much shorter periods in M/16 and M/32 salt solutions than they do in M/8 solutions. In the acid media, for reactions pH 5.8 to 6.8, M/16 and M/32 are the optimum salt concentrations, while M/8 solutions are less favorable. In other words, there appears to be an inverse relationship in the combined effects of salinity and reaction on larvae; in alkaline substrate a higher salinity is more favorable, while in acid substrates the higher salinity is less favorable.

This phase of the problem deserves more detailed study with more careful control of the variables, such as food, optimum temperatures, etc. Our experiments show that, on the one hand, the reaction effect is not so simple and clean-cut as MacGregor supposed and, on the other, that under a given set of limited conditions, the reaction may exert an influence on larval development, a fact which may be of value in limiting breeding under those conditions. The reaction effect cannot, however, be considered by itself without taking into account the salinity, food content, etc., of the water.

Observations in nature do not differ essentially from those recorded under experimental conditions. No species of anopheles other than *multicolor* has been found breeding in water with a salinity higher than 1 per cent. Larvae of *A. elutus* have occasionally been encountered in "brackish" water, but the salinity has always been less than 1 per cent, usually not higher than 0.5 per cent.

With regard to reaction, we have not been able to confirm MacGregor's observations. Perhaps this is owing to the fact that Palestinian waters are, with rare exceptions, alkaline. But the very fact that such a variety of anopheles are adapted to this reaction would suggest that MacGregor's observations were a special case, and an exception rather than the rule.

Effect of temperature.—Temperature exerts a decisive influence on the breeding of anopheles and, consequently, on their seasonal prevalence. The different Palestinian species have different tem-

perature optima. *A. bifurcatus* is distinctly a low temperature and hence a temperate or cold season species, and so is *A. algeriensis*. *A. elutus* and *M. superpictus* are intermediate in their temperature optima. *M. sergenti* is distinctly a high temperature or a subtropical species.

The effect of temperature is best studied in relation to the period required for the completion of the life-cycle at different temperatures. Roughly speaking, within certain narrow limits, the rate of development of anopheline larvae follows Van't Hoff's equation; that is, for every rise of 10° C., the period of development is reduced by half. This formula is, however, only approximately correct, because it does not take into account the upper and lower critical temperatures. At the low critical temperature, the time of development approaches infinity, while at the higher temperature, death sets in more or less promptly or, in other words, development ceases altogether. These critical temperatures are different for different species. Taking this into consideration, Blunck proposed a modified formula which takes into account the low critical temperature. The Blunck formula postulates that the product of the time of development (T) and the difference between the temperature (t) of the observation and the low critical temperature (c) is constant. That is: $T(t-c) = K$.

This is the formula of an equilateral hyperbola, and on the basis of two observations it is possible to calculate the value of c — the low critical temperature, and construct the development curves of insects whose larval development occurs in water (and, according to Bodenheimer, of other insects as well). The curves constructed on the basis of this formula accord closely with the observed relations of time and temperature under optimal nutritive conditions, *below the limits of the upper critical temperature*.

Using observed data on time of development at different temperatures, we have constructed curves for some of the local malaria vectors. The relation of the temperature to the life-cycle of these insects manifests itself most strikingly in the low critical temperatures. The low critical temperatures for *A. bifurcatus*, *A. elutus*, and *M. superpictus* are 8.0, 10.1, and 17.5, respectively. The close agreement between calculated and observed data is demonstrated by the accompanying curves as well as by the tables worked out by Ashner

CHART IVA

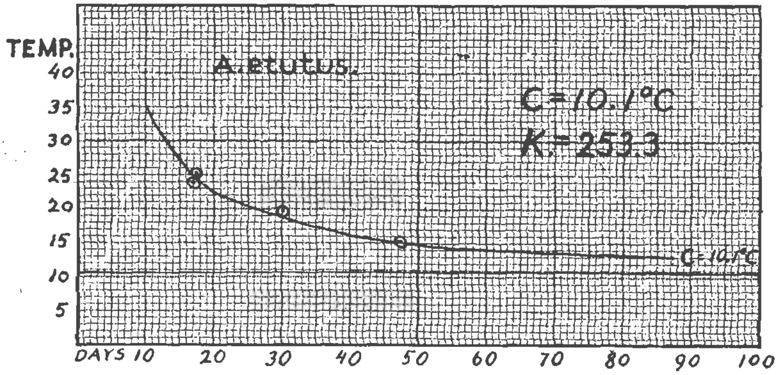


CHART IVB

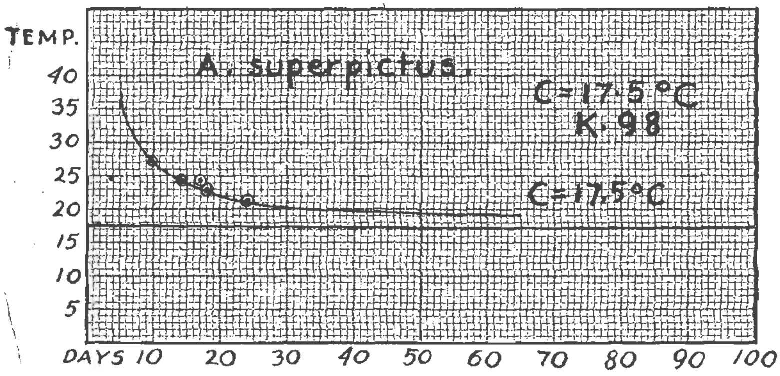
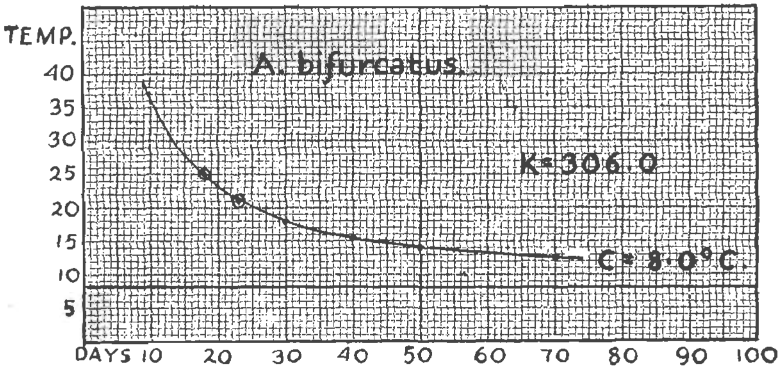


CHART IVC



Temperature Curves of Some Local Malaria Vectors

in our laboratory. These tables and charts give some of the observed data, calculated constants, and the theoretical and actually observed values; the plotted observed values are indicated by circles. An interesting point which seems to be quite constant is the observation

TABLE XV

Relation of Temperature to Anopheles Development

Observed Data Days					Calculated Data Days			
Temp.	Egg Stage	Larval Stage	Pupal Stage	Total	Temp.	Calculated Time	Observed Egg-Stage Days	Observed Egg-Stage ×7
				A. elutus				
15.5	7	37	4	48	15.5	50.0	....	....
19.0	2	24	4	30	19.0	28.0	....	....
24.0	2	12	3	17	24.0	18.0	....	....
25.0	2	13	2	17	25.0	17.0	....	....
....	......	....	....	....	15.0	58.0	8	56
....	......	....	....	....	16.5	40.0	6	42
....	......	....	....	....	18.0	35.0	5	35
....	......	....	....	....	19.0	28.0	4	28
....	......	....	....	....	23.0	20.0	3	21
....	......	....	....	....	27.0	14.4	2	14
				M. superpictus				
21.5	3	18	3	24	21.5	24.5	....	....
22.0	3	13	2	18	22.0	21.7	....	....
24.0	2	13	2	17	24.0	15.0	....	....
24.5	2	10	2	14	24.5	14.0	....	....
27.0	2	6	2	10	27.0	10.3	....	....
				A. bifurcatus				
21	4	....	....	23.5	....	....	....	....
25	3	....	....	18.0	....	....	....	....

that the egg-hatching time is exactly one-seventh of the total period of development. This seems to hold true also for *M. superpictus*, but the number of observations on this species is not so numerous as is the case for *A. elutus*. If this relation really proves a constant one for all species, it becomes a simple matter to determine exactly their period of development at various temperatures.

are also manifested by effects of high temperature. Just as the larvae of different species have different low critical temperatures so they seem to have different high critical temperatures. In various experiments performed by Ashner, it appears that *A. elutus* is much more sensitive to heat than *M. superpictus.* A few of these experiments are summarized in Table XVI.

TABLE XVI

COMPARATIVE EFFECT OF HIGH TEMPERATURES ON LARVAE OF A. ELUTUS AND M. SUPERPICTUS

Number of Larvae Exposed	To Degrees of Temperature	For Time, in Minutes	Results
6 superpictus...	41	30	All alive
4 elutus........	41	30	2 larvae alive which died next day
5 elutus 2 superpictus	41	30	4 elutus died next day; all superpictus well or pupated
4 elutus 9 superpictus	41	30	All elutus and 4 superpictus died
16 elutus 5 superpictus	41	30	1 superpictus alive
19 elutus 15 superpictus	41	30	17 elutus and 1 superpictus died
4 elutus 3 superpictus	40	50	Elutus died; superpictus alive
15 elutus 30 superpictus	39	140	14 elutus died; superpictus alive
13 elutus 11 superpictus	38	420	After 5–7 hours 10 larvae of elutus died, and 1 superpictus
8 elutus 6 superpictus	37	480	Next day elutus dead; superpictus well

There are other effects of temperature which have not been studied carefully as yet, and which play an important part in the life-cycle and habits of anopheles. Extreme high as well as low temperatures seem to exert a profound influence on the imago, both with respect to its activity and its egg-laying capacity. Theodor in our laboratory observed the remarkable fact that eggs of *A. elutus* laid during the winter have floats similar to, though smaller than, those of *A. maculipennis.* During other seasons of the year such floats have never been observed. Ashner, on the other hand, noted that the prevailing high summer temperature seems to limit the egg-laying capacity of *A. elutus*, whereas that of *M. sergenti* is apparently

in our laboratory. These tables and charts give some of the observed data, calculated constants, and the theoretical and actually observed values; the plotted observed values are indicated by circles. An interesting point which seems to be quite constant is the observation

TABLE XV

RELATION OF TEMPERATURE TO ANOPHELES DEVELOPMENT

Observed Data Days					Calculated Data Days			
Temp.	Egg Stage	Larval Stage	Pupal Stage	Total	Temp.	Calculated Time	Observed Egg-Stage Days	Observed Egg-Stage ×7
				A. elutus				
15.5	7	37	4	48	15.5	50.0	...	...
19.0	2	24	4	30	19.0	28.0	...	...
24.0	2	12	3	17	24.0	18.0	...	...
25.0	2	13	2	17	25.0	17.0	...	...
...	...	...	...	...	15.0	58.0	8	56
...	...	...	...	...	16.5	40.0	6	42
...	...	...	...	...	18.0	35.0	5	35
...	...	...	...	...	19.0	28.0	4	28
...	...	...	...	...	23.0	20.0	3	21
...	...	...	...	...	27.0	14.4	2	14
				M. superpictus				
21.5	3	18	3	24	21.5	24.5	...	...
22.0	3	13	2	18	22.0	21.7	...	...
24.0	2	13	2	17	24.0	15.0	...	...
24.5	2	10	2	14	24.5	14.0	...	...
27.0	2	6	2	10	27.0	10.3	...	...
				A. bifurcatus				
21	4	...	...	23.5	...	...	...	...
25	3	...	...	18.0	...	...	...	...

that the egg-hatching time is exactly one-seventh of the total period of development. This seems to hold true also for *M. superpictus*, but the number of observations on this species is not so numerous as is the case for *A. elutus*. If this relation really proves a constant one for all species, it becomes a simple matter to determine exactly their period of development at various temperatures.

The different temperature optima of various species of anopheles

are also manifested by effects of high temperature. Just as the larvae of different species have different low critical temperatures so they seem to have different high critical temperatures. In various experiments performed by Ashner, it appears that *A. elutus* is much more sensitive to heat than *M. superpictus.* A few of these experiments are summarized in Table XVI.

TABLE XVI

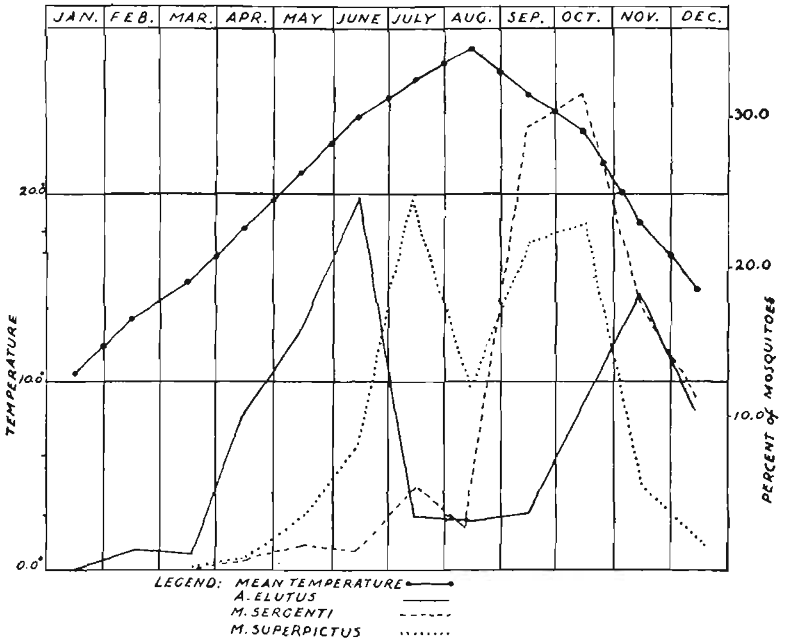
Comparative Effect of High Temperatures on Larvae of A. elutus and M. superpictus

Number of Larvae Exposed	To Degrees of Temperature	For Time, in Minutes	Results
6 superpictus...	41	30	All alive
4 elutus........	41	30	2 larvae alive which died next day
5 elutus, 2 superpictus..	41	30	4 elutus died next day; all superpictus well or pupated
4 elutus, 9 superpictus..	41	30	All elutus and 4 superpictus died
16 elutus, 5 superpictus..	41	30	1 superpictus alive
19 elutus, 15 superpictus..	41	30	17 elutus and 1 superpictus died
4 elutus, 3 superpictus..	40	50	Elutus died; superpictus alive
15 elutus, 30 superpictus..	39	140	14 elutus died; superpictus alive
13 elutus, 11 superpictus..	38	420	After 5–7 hours 10 larvae of elutus died, and 1 superpictus
8 elutus, 6 superpictus..	37	480	Next day elutus dead; superpictus well

There are other effects of temperature which have not been studied carefully as yet, and which play an important part in the life-cycle and habits of anopheles. Extreme high as well as low temperatures seem to exert a profound influence on the imago, both with respect to its activity and its egg-laying capacity. Theodor in our laboratory observed the remarkable fact that eggs of *A. elutus* laid during the winter have floats similar to, though smaller than, those of *A. maculipennis.* During other seasons of the year such floats have never been observed. Ashner, on the other hand, noted that the prevailing high summer temperature seems to limit the egg-laying capacity of *A. elutus,* whereas that of *M. sergenti* is apparently not affected. Apparently, there is also a direct relation between

temperature and fertility of the eggs; a smaller percentage of the eggs laid during the summer hatch than those at other seasons. The temperature also appears to be the factor chiefly concerned in the hibernation flight, exerting an effect similar perhaps to that in the swarming of birds, the nature of which is but little understood.

CHART V



Relation of Mean Temperature to Mosquito Prevalence

Seasonal prevalence.—The seasonal prevalence of anopheles is directly related to temperature. *A. elutus* begins to breed about the middle of March, and continues until the beginning of the heavy rains, at the end of November or sometime in December. From about the middle of August to the middle of October, there is a decided diminution in numbers or practical disappearance of *A. elutus;* at the latter period there is again a sharp increase. The period of activity of *M. superpictus* follows closely that of *A. elutus.* Its larvae appear at the end of March, but it breeds slowly in the spring, reaching a maximum in July while the second fall peak is

reached in September-October and not in November, as in the case of *A. elutus*. The active season of *M. sergenti* is equally well defined. Its larvae usually become evident in June, but active breeding does not begin until the end of August. The adult is practically absent during the spring and summer, but is the dominant mosquito throughout September and October. After that month they decrease in numbers, while *A. elutus* increases. In general there is considerable local fluctuation in the extent of the breeding period, due apparently to variations in temperature from place to place and year to year. The relation of temperature to mosquito prevalence is shown in Chart V and Table XVII.

TABLE XVII

MEAN MONTHLY TEMPERATURE AND RELATIVE PREVALENCE OF THE DIFFERENT SPECIES OF ANOPHELES

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Temperature in C°	*12.4	13.3	15.3	18.1	21.2	24.0	26.0	26.6	25.2	23.2	18.3	14.5
A. elutus..	†	1.3	0.9	11.3	12.5	24.4	3.4	3.0	3.7	11.5	18.0	10.0
M. sergenti	.....	0.0	0.4	0.5	1.5	1.1	5.5	2.6	29.0	31.3	17.0	11.0
M. superpictus...	.....	0.5	.....	0.5	3.5	8.0	24.5	11.9	21.5	22.7	5.3	1.5

* The mean monthly temperature is the mean of the mean temperatures for the stations Gaza, Sarona, Haifa, and Jenin– stations located along the coastal and inland plains.

† The figures express the percentage of the total catch of the given species in various representative stations in different parts of the country throughout the year. Thus, these figures give approximately the relative abundance of each species at different seasons.

ACTIVE PERIOD OF ADULT ANOPHELES

The *adult* mosquitoes are of course most active during the height of the breeding season, but they may be said to be active throughout the year. Although mosquitoes seek winter quarters, there is no complete hibernation in Palestine. During the months January to March, one frequently finds mosquitoes with freshly ingested blood; while in the laboratory they feed and lay eggs readily when the room temperature is between 15° and 17° C. In general the low temperatures which prevail throughout the winter (10° to 12° C. in the plains) greatly inhibit their activity. Between the rains, during the longer periods of sunshine, the temperature often rises to 16° or 18° C., and the anopheles resume their activity. During these intervals the imagos may even leave their shelter to lay eggs and return to feed.

These periods of resumed activity account for the sporadic cases of primary infection which actually occur during the winter months, and also for the presence of larvae early in March in places which were dry at the end of December.

The local house-visiting anopheles survive the winter chiefly as adults. All of the house-visiting anopheles are found in considerable numbers in the different sections of the country throughout the winter months. The mosquitoes taken in the winter are all females with stored fat and partially developed ovaries; males are practically never seen. The great majority of mosquitoes, as may be seen from the tables, are found in the warmer storehouses, cellars, and stables in preference to sleeping- and living-rooms. However, as indicated above, one often finds mosquitoes with recent blood feed, and we have noted repeatedly, on warm days, *A. elutus* trying to leave or enter houses. Some of them probably enter, take their feed, and return to the warmer storehouse for shelter.

ACTIVITY OF IMMATURE STAGES

The activity of immature stages is more limited to certain seasons of the year than that of the imagos. Careful and repeated search made in the various breeding-places in different parts of Palestine during the winter months failed to reveal breeding. As a rule, no anopheles larvae are found during January anywhere except on the banks of the Sea of Galilee near Migdal. In this area, larva of *M. sergenti* have been found beneath the gravel up to January 15, but not later. At the time the larvae were found, the temperature of the water at this point was 17° C., while, in various other sections of the country, it ranged between 12° and 10° C. During February, no larvae or pupa of *elutus*, *sergenti*, or *superpictus* have been found anywhere. In March (March 4–31), anopheles larvae again make their appearance in various places in different parts of the country. The exact date when larvae reappear seems to depend on the temperature. The larvae usually reappear when the day air temperature is 20° C. or over, and the mean water temperature ranges between 18° and 22° C. The great majority of larvae taken during early March are *A. algeriensis*, but a few *A. elutus* also are encountered; these are the first larvae of the house-visiting anopheles to

make their appearance. Larvae of *M. superpictus* are not found until the end of March or early in April.

TABLE XVIII

HIBERNATION OF ADULT ANOPHELES*

(1923)

Place	Numbers Found in: Living, Sleeping Rooms	Numbers Found in: Stables, Cellars, and Storehouses	Species Found: *A. elutus*	Species Found: *M. superpictus and M. sergenti*	Species Found: Other Species	Month
Coastal Plain:					multicolor	
Zichron........	144	217	342	0	19	February
Shuni..........	52	58	93	5	12	February
Tel Zur........	14	20	35	0	0	February
Hedera........	4	*64*	*64*	4	0	*February*
Gan Shmuel....	2	19	21	0	0	February
Hefzi Bah......	55	63	118	0	0	February
Karkur........	1	22	33	0	0	February
Upper Galilee:						
Rosh Pina.....	0	0	0	0	0	March
Mahanaim.....	6	0	6	0	0	March
Ayeleth........	0	12	0	12	0	March
Mishmar......	38	40	76	2	0	March
Yessod........	57	35	90	2	0	March
Lower Galilee:						
Kinnereth.....	0	128	32	96	0	Jan.–March
Dagania.......	12	36	32	16	0	Jan.–March
Bethania......	0	27	19	8	0	Feb.–March
Menahemia....	0	12	5	7	0	Feb.–March
Yabniel........	3	125	6	122	0	Feb.–March
Beth Gan......	0	8	0	8	0	Feb.–March
Meskha,.......	0	0	0	0	0	Feb.–March
Valley of Esdraelon:						
Nahalal.......	1 (in tents)	4	12	8	0	Jan.–Feb.
Merhavia......	22	264	250	36	0	Jan.–Feb.
Tel Adashim...	3	39	33	9	0	Jan.–Feb.
Balfouria......	0	0	0	0	0	Jan.–Feb.
Ein Harod.....	0	29	20	9	0	Jan.–Feb.
Judea:						
Ein Ganim.....	0	6	6	0	0	March
Mahneh Yehuda	0	0	0	0	0	March
Ekron.........	7	34	7	34	0	February
Hulda.........	5	0	0	5	0	February
Kfar Uria......	0	8	5	3	0	February
Artuf..........	3	1	1	0	3 bifurcatus	February
Rishon........	0	0	0	0	0	February
Nahlat Yehuda.	0	1	0	1	0	February

* This table requires a few explanatory remarks: (1) The figures are not absolute but representative. (2) *M. superpictus* and *sergenti* were not differentiated by the malaria inspectors; those specimens which were sent to the laboratory were all *superpictus*. (3) It is noteworthy that in the Coastal Plain and in Upper Galilee (except Ayeleth) *A. elutus* was practically the only species found; in the Yabniel district *M. superpictus* and *sergenti* were the sole species; in other areas all three species were found.

In general our observations over a period of years indicate that hibernation in the immature stages is an infrequent occurrence. Nevertheless, this is undoubtedly one form of survival. *Superpictus*

TABLE XIX

HIBERNATION OF ADULT ANOPHELES

(1927)

January

PLACE	NUMBERS FOUND IN		ELUTUS	SERGENTI	MALES
	Rooms	Stables			
Yabniel	63	303	191	171	1
Beth Gan	28	205	140	93	2
Segera	5	129	103	31	0
Menahemia	42	335	231	146	1
Kinnereth	29	757	665	111	0
Kinnereth (co-operative group)	32	215	242	5	0
Dagania A	36	508	496	38	0
Dagania B	15	194	209	0	0
Bethania	18	223	188	53	0
Rosh Pina	875	3,406	3,575	706	0
Mahanaim	56	1,235	1,171	120	0
Ayeleth	36	959	959	36	0

February

PLACE	FIRST WEEK				LAST WEEK			
	Rooms		Stables		Rooms		Stables	
	Elutus	Sergenti	Elutus	Sergenti	Elutus	Sergenti	Elutus	Sergenti
Kinnereth	3	0	63	35	......	......	71	28
Kinnereth (co-operative group)	......	......	......	......	......	......	32	3
Dagania A	4	0	57	0	1	0	26	1
Dagania B	1	0	23	0	......	......	28	0
Rosh Pina	172	10	2,364	90	......	......	......	......

NOTE.—The marked reduction in February is due partly to a systematic destruction of hibernating mosquitoes carried out during January. During February one *A. bifurcatus* was taken in Jerusalem.

eggs have been kept in the laboratory three and a half weeks before they hatched. Larvae of *A. elutus* and *M. superpictus* remained alive from four to five weeks. When the temperature was below 12° C., they sank to the bottom and remained supine and motionless. When the temperature rose to 14° C. or over, they rose to the top and resumed their normal activity. This is evidently the reason why dur-

ing the winter months no larvae are in evidence, while some time during the month of March they suddenly appear half or full grown. Often early in the season one sees no sign of larvae in the morning, but finds them readily in the same place during the afternoon of the same day.

TABLE XX

EARLIEST AND LATEST DATES OF DETECTION OF ANOPHELES LARVAE

Place	District	Type of Anopheles	Date
	Earliest Larvae		
Hedera	Samaria	A. elutus	March 4
Kinnereth	Galilee	A. elutus	March 6
Yabniel	Galilee	A. elutus	March 12
Nahalal	Esdraelon	A. elutus	March 19
Kabbara	Samaria	A. elutus	March 20
Merhavia	Esdraelon	A. elutus	March 21
Yazur	Kishon Valley	A. elutus	March 20
Ein Harod	*Esdraelon*	*M. superpictus*	*March 28*
Beth Alpha	Esdraelon	M. superpictus	March 28
Ayeleth	Upper Galilee	M. superpictus	March 24
Menahamia	Lower Galilee	M. sergenti	March 27
Tel Yoseph	Esdraelon	M. sergenti	March 27
	Latest Larvae		
Tel Yoseph	Esdraelon	A. elutus	November 5
Merhavia	Esdraelon	A. elutus	November 15
Benjamina	Samaria	A. elutus	November 27
Bethania	Galilee	M. sergenti	December 5
Zarain	Esdraelon	M. sergenti	December 11
Beth Alpha	Esdraelon	M. sergenti	December 14
Tiberias	Galilee	M. sergenti	December 30
Tel Yoseph	Esdraelon	M. sergenti	January 15
Ein Harod	Esdraelon	M. superpictus	November 13
Balfouria	Esdraelon	M. superpictus	December 2
Zichron	Samaria	M. superpictus	November 6

The presence of larvae does not signify active breeding. Larvae of *M. sergenti* may be taken until the middle of January, but active breeding ceases in October or November. The active development of larvae is, as indicated in the foregoing, directly a function of temperature (other conditions being normal). The curve of the activity of breeding corresponds with that of the abundance of adult anopheles, and the curves showing prevalence of imagos given above are typical. The exact time for cessation of breeding cannot be stated

with certainty, because it depends to a considerable extent on the date when the heavy rains begin, which in Palestine is subject to marked fluctuations.

FLIGHT OF MOSQUITOES

Knowledge of the extent to which mosquitoes can spread from their breeding-places is essential to effective control of malaria. Without such knowledge, it is impossible to define the limits of a control zone. Nevertheless, the amount of exact information on this point is still very scant.

There are only a few records of actually measured flights. The first was made by Le Prince in Panama. Similar experiments were subsequently carried out by Le Prince and Griffiths in 1916 and by Tarbet in 1917. The results of these experimental flights indicated that a small number of mosquitoes stained and released at a given point can be recaught at a distance of three-fourths to 1 mile from the point of release. Sella reported in 1920 flight experiments in which *A. claviger* was recovered in small numbers 2½ kilometers from the point of release.

The general field observations on record are equally few in number and not so precise as the actual flight experiments. These observations also indicate that anopheles mosquitoes can fly from 1 to 1½ miles from a breeding focus to a place of habitation. On the basis of these observations the arbitrary limits of approximately 1 mile is generally adopted as a more or less standard control zone.

At the commencement of the control work in Palestine, a zone of 1.5 kilometers about a settlement was accepted as a safe distance. In several instances, however, there seemed to be ample proof that under certain conditions prevailing in some sections of rural Palestine, mosquitoes came in considerable numbers from distances greater than 2 kilometers. It became necessary, therefore, to define with a greater degree of accuracy the average distance of flight of the native species of house-visiting anopheles.

There are two methods available for a study of this character. One is to ascertain the distribution of a given species of anopheles at different distances from its breeding-place. The other is to stain mosquitoes, release them, and identify the stained specimens among mosquitoes caught in various places.

The second method is apparently the more accurate one; but we are convinced by our experience that this accuracy is only apparent. The catching, handling, and staining of mosquitoes causes a greater or lesser degree of injury, which must necessarily affect their capacity for long-distance flight. In all the flight experiments on record, the total number of stained mosquitoes recovered at a distance of one kilometer or more from the point of release was less than 1 per cent of those released. Besides the injury due to the handling, there is also the possibility of the disappearance of the dye. Moreover, the number of mosquitoes that can be sent off on test flights is relatively small in comparison with the numbers emerging from an actively breeding marsh. Our own experience with this method has been disappointing.

The first method is more likely to yield information which corresponds to the events occurring in nature, provided that the observations are carefully checked and controlled. It is essential to make sure that there are *no other breeding places* of the particular type of mosquito in question and that its concentration in various parts of the settlement leaves no doubt as to the source.

Using this method, a large amount of interesting data has been collected during the last few years bearing on the distance of flight of some of the local anopheles. From these observations it appears that while the average flight under the usual conditions prevailing here may be approximately 2 kilometers, under certain other conditions the distance traversed may be considerably greater. Both *M. sergenti* and *A. elutus* have a much greater range of flight than is commonly supposed. In Hedera *A. elutus* traverses a distance of 2.4 kilometers from the settlement, and causes recurrent epidemics. In the Ekron District the Melat Swamp has been proved to be the cause of malaria in Naaneh and Ekron, 2 and 2.25 kilometers away. In Beth-Alpha, *M. sergenti* came from a swamp 2.5 kilometers from the settlement. These and other observations are not open to question, because no other breeding-place could be found nearer to the settlement to account for the presence of the given species of mosquitoes which disappeared with the control of the suspected breeding-places.

In considering the flight of anopheles, one must differentiate three distinct phases: (1) direct flight from a breeding-area, (2) dis-

persion during the active breeding season, and (3) dispersion just prior to hibernation. It would appear that one of the reasons for the disappointments in attempts to control malaria by anti-mosquito measures has been a lack of appreciation of the range of influence of an intense anopheles-producing marsh.

It is quite certain that the various species of house-visiting anopheles in Palestine have a direct flight range of about 2.5 kilometers (1.5 miles). This has been shown repeatedly in many places at this distance from the marsh with no other houses or village intervening.

Of even greater interest is the observation made on various occasions indicating that the *range of dispersion* during the active breeding season may be at least 3.5 kilometers. "Range of dispersion" signifies the diffusion of anopheles from a highly infected village two kilometers or less from a marsh in which breeding is intense, to neighboring villages much farther away. The occurrence of this diffusion is established in two ways: (1) by the absence of other breeding-places in the vicinity, and (2) by the relative density of mosquitoes found at various points in the direction of the swamp. A good example is the experience in the region of the Kishon. A small epidemic developed in a new settlement (Nahlat Jacob) established at a point 3.5 kilometers from the uncontrolled part of the stream. About 1.5 kilometers from this settlement was a native village, Sheikh Abreik, which in turn was 2.25 kilometers from the Kishon. While isolated female anopheles (never more than ten in fifty barracks) with developed ovaries were found daily in Nahlat Jacob, males and young females were never encountered there. In Sheikh Abreik, on the contrary, the daily numbers of anopheles ran in the hundreds, and males were found regularly. This condition continued until the area under control was extended, and the village Sheikh Abreik freed from mosquitoes. As soon as the mosquitoes in the village were reduced in number, Nahlat Jacob became absolutely free of anopheles.

The range of dispersion during the hibernation flight in November and December is even greater. Ranana and Herzlia in Judea and Mahanaim, Rosh Pina, and Kfar Giladi in Upper Galilee have experienced mass invasions, particularly of *A. elutus*, at the end of

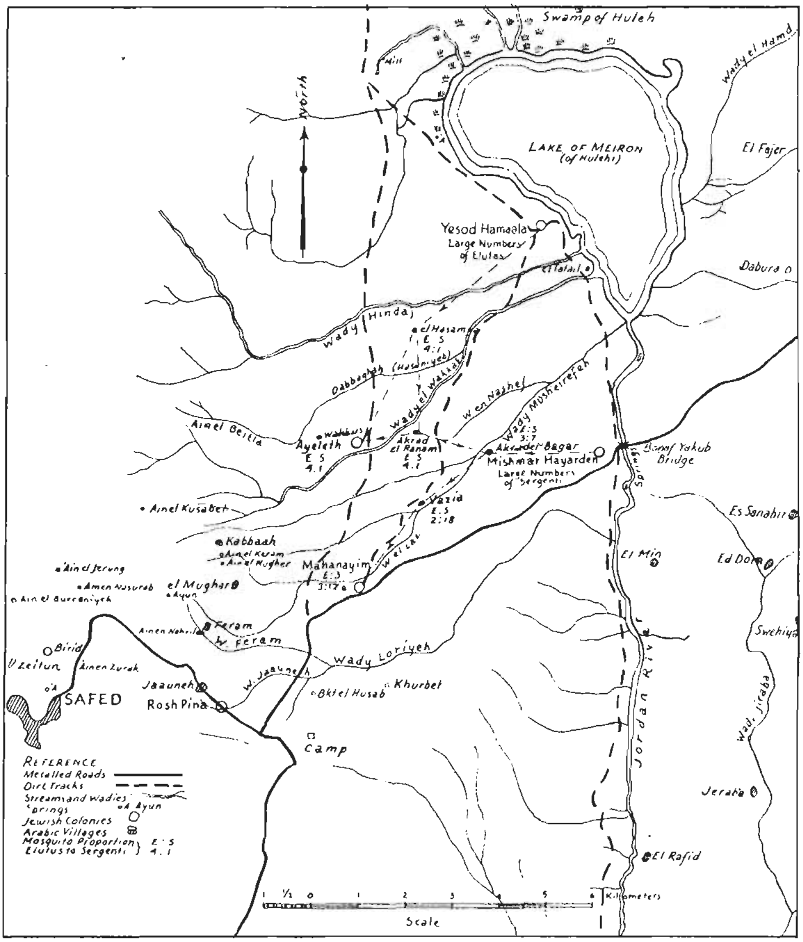
the year. The only apparent sources of these mosquitoes were Birket Ramadan and the Huleh, 6 and 12 kilometers from the respective settlements. This experience has been duplicated in several places. Indeed, the problem of hibernation-dispersion appears to be a serious one. This flight or dispersion begins toward the beginning of November, sufficiently before the activity of the adult anopheles is at an end, so that late epidemics may result, such as occurred in Rosh Pina in 1923, 1924, and 1926, and in Ranana and Herzlia in 1925. The distinguishing characteristic of this dispersion is an epidemic outbreak in December in places almost entirely free from malaria during the rest of the year, that is, during the usual epidemic season.

The accompanying map illustrates the probable distribution or dispersion of mosquitoes from two foci. It shows the results of an anopheles survey made by H. Saliternik, the senior inspector of the Malaria Research Unit. Starting from Mishmar, a focus of *M. sergenti,* and Yessod, a focus of *A. elutus,* he traced their path by ascertaining the relative numbers and proportion of these two species in the various villages in that region. The predominance of *sergenti* in the villages nearer Mishmar and *elutus* in those nearer Yessod, and the mixture of the two species in various proportions in the more remote villages, indicate both the direction of their flight and their diffusion. It constitutes a clear demonstration that the flight of mosquitoes is not a simple single line route of travel from a breeding focus. More might be learned regarding this phenomenon to the advantage of malariologists.

An important point in connection with the flight of mosquitoes is often overlooked. They do not come when the wind is strong, but when it is gentle or when it has subsided. While strong winds are blowing the mosquitoes seek shelter, and are not active. The direction of the wind is, therefore, not so important as is generally supposed. The range of flight and dispersion are regulated by factors which are more important than the direction of the wind. The distance of flight depends more on the intensity of breeding, the number and density of houses and settlements, and their proximity to the breeding-places. The distance of spread from a breeding-focus varies directly with the intensity of breeding and inversely with the density of the settlements and population. If there are no settle-

ments near the swamps, or if the breeding is very heavy, the mosquitoes travel relatively long distances in order to obtain their food, Bedouin tents and isolated houses serving as way stations.

MAP IX



AYELETH, ROSH-PINA DISTRICT
Showing Dispersion of Mosquitoes as Found during September, 1926

PREFERENTIAL FEEDING HOSTS

Roubaud advanced the hypothesis that anopheles, particularly *A. maculipennis*, show preference in their feeding, and prefer cattle

to man. Bull and King, in carefully controlled experiments, failed to confirm this view. In an extended series of observations, using the blood precipitation test devised by Bull, our results also failed to confirm the observations of Roubaud. Mosquitoes taken in stables contained only animal blood (63 per cent cow and 37 per cent horse and donkey), while of those taken in houses 70 per cent contained human and 30 per cent animal blood (23 per cent cow and 8 per cent horse and donkey). The stables, as a rule, contained from four to seven times as many anopheles as the dwellings. But in proportion to the size and number of animal hosts this ratio was much reduced.

Our observations indicate that the local anopheles do not show *animal* preference but *house* preference. Certain stables are invariably preferred to others, just as certain houses have a greater attraction for anopheles than others. We have seen living quarters which attracted anopheles more than did the stable. After a little experience, the local inspector will come to know the specific houses and stables in a given village having the greatest concentration of mosquitoes. One may really speak of anopheles houses and anopheles stables. Shelter, hiding places, temperature, and humidity probably all play a part. After a stable was cleaned and whitewashed, all boxes and food bins removed, and full access of light given, a place noted for the large numbers of anopheles caught daily became practically mosquito-free. By darkening the stable, returning the trappings and hangings, the attractiveness was restored and the concentration of mosquitoes re-established.

This problem of house preference is just as important as breeding preference. It is not at all unlikely that adult traps may prove as useful in mosquito control as are the larvae traps proposed by Carter. The behavior of adult anopheles requires more careful study than has been accorded it in the past.

DISTRIBUTION OF THE VARIOUS TYPES OF ANOPHELES

The various species of anopheles are not uniformly distributed throughout Palestine, and this difference in distribution depends not on climate but on the character of the breeding-places prevailing in the different districts. Thus in Ein Ganim, Hedera, and elsewhere in Judea and Samaria, where shortly after the rains the wadis

present the appearance of a series of isolated stagnant pools, *A. elutus* is found; while in wadis Melat and Musrara, also in Judea, fed by springs, and consequently having a continuous slow-moving stream, *M. superpictus* and *M. sergenti* are found.

In Judea both *A. elutus* and *M. superpictus* are found, but the latter predominate where the breeding-places are caused by springs (Ekron, Artuf, Ramath Gan), and the former are practically the only house-visiting anopheles where the breeding-place is a winter wadi (Ein Ganim).

In Samaria (Hedera area) along the coast, *A. elutus* is practically the only house-visiting anopheles; but *M. superpictus* is occasionally found and, rarely, also *M. pharoensis.*

In Phoenicia (Zichron Jacob and Athlit) *A. elutus* is the dominant type, but *M. multicolor* is found in the salt marshes and *M. superpictus* in the spring wadis. The latter are, however, uncommon in comparison with *A. elutus.*

In the Valley of Esdraelon, *A. elutus*, *M. superpictus*, and *M. sergenti* are equally abundant. The first two are more prevalent in the spring and late fall, and the last are more numerous in the late summer and fall.

In Lower Galilee in the Yabniel area, *M. superpictus* and *M. sergenti* are practically the only species encountered. In this district, the only breeding-places are the seepage canals and flowing wadis. Along the Jordan and the Sea of Galilee, *A. elutus, M. sergenti,* and *M. superpictus* are equally common. *A. elutus* breeds along the shores of the Jordan in the beds of ranunculi, or in the swampy areas where the low ground is flooded by the Jordan. *M. superpictus* breeds in the flowing wadis, and *M. sergenti* is found in the seepage from the irrigation canals and under pebbles and rocks in the wadis or in the Jordan.

In Upper Galilee (Rosh Pina area), *A. elutus* is the principal species, but *M. superpictus* is commonly found. In the late summer and fall, *M. sergenti* is also found but in relatively smaller numbers.

Occasionally, one also finds the urban mosquito *A. bifurcatus* breeding in cisterns. This mosquito was found by us in cisterns in Artuf (Ekron area) and in Poria (Yabniel area) and Yessod (Rosh Pina area).

TABLE XXI

TYPES OF BREEDING-PLACES AND MOSQUITOES FOUND IN THE VARIOUS DEMONSTRATION AREAS

District	Types of Breeding-Places	Average Distance in Kilometers from Settlements	Prevailing Types of Anopheles
Petah Tikvah (Judea)	Reservoirs in orange groves, winter wadis, seepage wadi	0.10 –4.50	elutus++++* superpictus++ sergenti+ pharoensis *r*† algeriensis++ hyrcanus+
Ekron (Judea)	Winter wadis, springs and wadis, seepage areas, watering holes, reservoirs	0.00 –2.20	elutus+++ superpictus++ sergenti+ multicolor+ bifurcatus+
Hedera (Samaria)	Winter wadi, rain water basins, seepage areas, seepage wadis, springs, and canals	0.00 –2.50	elutus++++ superpictus ± sergenti ± pharoensis *r* algeriensis++ hyrcanus+++
Zichron Jacob (Phoenicia)	Kabbara swamp, ground-water outcrops, springs and wadis, irrigation canals, Zerka river, barrow pits	0.10 –2.00	elutus++++ superpictus+ sergenti ± multicolor+ pharoensis ± hyrcanus++ algeriensis++
Merhavia (Valley of Esdraelon)	Springs, seepage wadis, watering holes, wells	0.20 –1.75	elutus+ superpictus+++ sergenti+++ multicolor *r* algeriensis+
Ein Harod (Valley of Esdraelon)	Springs and wadis, seepage areas, flour mills with overflow swamps, irrigation canals, canal for water supply, shallow river bed and swamp	0.00 –2.50	superpictus+++ sergenti++++ elutus++ pharoensis *r*
Kinnereth (Jordan Valley)	Stagnant pools on river banks, overgrown Jordan shores, seepage from Jordan into low irrigation canals, open wells, springs, wadis, leaking mill channels, seepage areas	0.25 –2.25	elutus++++ superpictus++++ sergenti++++ pharoensis *r*

* + indicates approximate relative prevalence.

† *r* means rare.

TABLE XXI—*Continued*

District	Types of Breeding-Places	Average Distance in Kilometers from Settlements	Prevailing Types of Anopheles
Yabniel (Lower Galilee)	Springs and wadis, seepage areas, irrigation canals, wells, cisterns	0.50 −1.25	elutus++ superpictus++++ sergenti+++ bifurcatus+
Rosh Pina (Upper Galilee)	Springs and canal reservoirs, seepage wadis, leaking mill run, puddles on lake shore, Huleh swamps	0.25 −2.25	elutus++++ superpictus++++ sergenti++++ algeriensis++ pharoensis+ bifurcatus+

RELATIVE IMPORTANCE OF THE VARIOUS SPECIES OF ANOPHELES AS MALARIA VECTORS

Happily not all the anopheles mosquitoes enumerated in the foregoing table are of equal importance as malaria vectors. The information on this subject is not yet complete. It is fairly certain, however, that *A. hyrcanus* and *A. algeriensis*, which are not house-visitors, are negligible in so far as malaria transmission in Palestine is concerned. *A. bifurcatus* is of great importance in the urban and rural highland districts which depend on cisterns for their water supply; but it is of relatively little significance in the rural communities in the foothills and plains which derive their water supply from springs or wells and not from cisterns. *M. multicolor*, the salt-water species, is of comparatively limited distribution, and judging from epidemiological evidence is not seriously concerned in the spread of malaria. The three remaining common species of anopheles are, undoubtedly, important vectors.

INCIDENCE OF INFECTED MOSQUITOES

Although a considerable number of dissections has been made, there is not yet sufficient evidence to warrant a definite statement regarding the relative incidence of infection among the different species. The results thus far indicate that the incidence varies in different places but is not unusually high. Among 2,400 *A. elutus* dissected during different months of the year, twenty-nine were found infected; an infection rate of 1.2 per cent. The highest incidence of

infected elutus was in the months of August, September, and December; the percentages being 2.2, 3.0, and 2.3, respectively. Evidently, the older the mosquitoes the greater is the incidence of infection. It is important to note that *elutus* infected with sporozoites were encountered in January and March, indicating that the parasites survive the winter months. Table XXII indicates the distribution of infected *elutus* throughout the year. The significance of these data will be discussed in connection with the epidemiology of the disease.

TABLE XXII

INCIDENCE OF INFECTED A. ELUTUS AT DIFFERENT MONTHS OF THE YEAR

Months	No. Dissected	No. Positive	Per Cent Positive
January	235	2	0.9
February	122	0	0.0
March	71	1	1.4
April	105	0	0.0
May	218	0	0.0
June	299	5	1.7
July	244	3	1.2
August	230	5	2.2
September	66	2	3.0
October	272	5	1.8
November	263	2	0.7
December	260	4	2.3
Total	2,385	29	1.2

NOTE.—Of the 334 superpictus dissected, 5 were positive, or 1.5 per cent; of the 195 sergenti, 1 was positive, or 0.5 per cent.

The numbers of *sergenti* and *superpictus* dissected were much smaller. The percentage found infected was 0.5 for *sergenti* and 1.5 for *superpictus*. These figures will undoubtedly require revision after a larger number of dissections have been made.

INFECTIVITY OF LOCAL ANOPHELES

All the three species referred to above may be readily infected with either *P. vivax* or *Pl. falciparum*. It has not been possible to ascertain conclusively whether the same percentage of each species will become infected when fed on the same patient at the same time. Comparisons of this sort require a large number of infections. Under optimal temperature conditions, that is from 25° to 28° C., and a moderate infestation of malignant tertian gametes (one gamete to

from ten to five leucocytes) from 50 to 75 per cent of the mosquitoes became infected.

Of greater significance are the observations bearing on the effects of temperature and of quinine ingestion by the patient on the development of parasites in the anopheles. The results bearing on the general problem of the relation of temperature to the development of sporozoites in various species of anopheles are not conclusive. One effect was, however, consistently obtained. At low temperatures, ranging between 9° and 17° C. the malignant tertian parasites failed to develop in the mosquito. In one experiment a number of *A. elutus* were fed on a patient having from two to three gametes per microscopic field (under oil immersion). Sixteen mosquitoes survived

TABLE XXIII

RELATION OF TEMPERATURE TO INFECTIVITY OF MOSQUITOES

Temperature During Experiment, C.°	Type and No. of Gametes, per Field	No. of Anopheles Fed	No. Survived	Time of Survival in Days	Results
15–18	M.T. 2–3	9	5	17–23	All negative
5–14	M.T. 3–5	21	5	11–28	All negative
5–14	M.T. 2–4	22	4	16	All negative

from fifteen to twenty-three days. Of these only one, dissected on the twenty-third day, contained ten small cysts. The temperature during the period of observation ranged from 14.5° to 17° C. Other experiments summarized in Table XXIII yielded the same results.

Patients heavily infected with gametes were selected for these experiments, but the results were uniformly negative. It appears that mosquitoes feeding at the low temperatures prevailing during the winter fail to become infected. This is quite a different matter from the survival of the infection during the winter in anopheles infected at a higher temperature during the warmer months.

The effect of quinine on malignant tertian gametes is the same as that observed by Mayne and by Wenyon. Quinine treatment has no effect on the infectivity of the malignant tertian gametes for mosquitoes. This fact is clearly shown in Table XXIV, summarizing our experiments.

TABLE XXIV

INFECTION OF ANOPHELES WITH GAMETES UNDER THE INFLUENCE OF QUININE

POSITIVE RESULTS

Day of Infection	Number of Mosquitoes Infected	Quinine Treatment	Type and No. of Gametes	No. of Mosquitoes Survived Seven Days or More	No. of Positive	Remarks
17/10/23	6 elutus	Up to 3 days before exper. daily 1 gm. quinine, 3 last days nil	M.T. 6–8 per field	4	3	Dissected on 7th and 9th day; young cysts
20/8/24	12 elutus	No quinine 8 days before	M.T. 2–3 per field	1	1	Dissected on 7th day; small cysts
19, 20 and 21/9/24	13 elutus	On 19/11, 1.5 oz. solution in the morning; 9 elutus fed On 20/11 no quinine; 2 elutus fed; on 21/11, 0.5 oz. shortly before feeding; 2 elutus fed	M.T. 2 per field	8	5	On 27/9 very small cysts on stomach; 1/10, 4 very heavy infections, large cysts and ripe sporozoites
9/10/24	17 sergenti	For 4 weeks up to 2 days before feeding daily 1 gm. quinine, but not regularly	M.T. 1 in 12–15 fields	13	7	Dissected on 13th, 14th, and 15th day; large cysts, only 1–2 in each; on 14th day mature cysts
12/11/24	19 elutus	For 4 weeks until 3 days before exper., every day 0.3 gm. quinine; 3d day before feeding 2/3 gm., 2d day before feeding 2/3 gm., 1 day before feeding 3 oz. solution, day of feeding 1½ oz. solution.	M.T. 1 in 3 fields	3	1	Dissected on 12th day; very young cysts
15/8/25	26 elutus and superpictus	Day before feeding 0.8 gm. per os; day of feeding 0.5 gm. injected in the morning. 20 superpictus and 6 elutus fed between 12 and 1	M.T. 1–8 leucocytes	1 elutus 1 superpictus	2	Dissected on 10th day, large cysts; temp. 27°
31/8/25	26 elutus and superpictus	Day before feeding 1 oz. solution; 2 and 3 days before, 3 oz. solution.	M.T. 1–20 leucocytes	1 superpictus	1	On 13th day sporozoites in salivary glands; temp. 27°–28°
8/9/25	27 elutus	No quinine	M.T. 1–10 leucocytes	3	1	On 5th day, large cysts; temp. 28°–30°

TABLE XXIV—*Continued*

NEGATIVE RESULTS

Day of Infection	Number of Mosquitoes Infected	Quinine Treatment	Type and No. of Gametes	No. of Mosquitoes Survived Six Days or More	No. of Positive	Remarks
26/9/23		Injection 2 gm. 1 day before feeding	B.T. large number 1 M. T. in 10 fields	4	0	Dissected on 6th, 12th, 18th, 19th day; negative
2/10/23		2 days before exper. 1 cc. 50% solution injected, 2 hours before 1 gm. solution per os	2 quartana per field	9	0	Dissected on 11th day; negative
1/10/23		3–5 days before exper. daily 1 gm.; 2 days before 1 cc. injection, and $1\frac{1}{2}$ gm. in solution per os	M.T. 1 in 2 fields	4	0	Dissected on 11th and 16th day; negative
3/1/24		3d and 2d day before feeding, 3 oz.; day before nil, and day of feeding 1 oz. solution	B.T. 1–2 fields	9	0	Dissected on 15th, 17th, 20th, 24th, 27th, 35th, 37th day; all negative; temp. 13°. 2–17°

CHAPTER V

INCIDENCE AND ETIOLOGY OF MALARIA

MALARIA PRIOR TO AND DURING THE WAR

The literature on malaria in Palestine prior to the war is scanty. The earliest publication on the subject is the report by Dr. H. Joffe (1900) on his studies on blackwater fever. Cropper (1901) made a detailed investigation of localities reputed to be malarious and concluded that malaria was prevalent wherever anopheles represented the majority of mosquitoes in the houses. He reported that the Jewish colonies Hedera, Tantura and Yessod suffered severely from malaria. Later (1904–5) Cropper studied the prevalence of malaria in Jerusalem and Ramallah. Of 937 outpatients at the dispensary in Jerusalem between September 13 and December 31, 1904, 424 suffered from malaria. Even in the then outlying parts of the city (Mea Shearim) the spleen rate at that time was 60 per cent.

In 1910 Aaron Aaronsohn, at that time director of the Agricultural Experiment Station at Athlit, sent a private report to Mr. Nathan Straus calling attention to the high incidence of malaria in the rural Jewish settlements and urging the need of some efforts to check the disease. In August of that year the first attempt at malaria control in Palestine was started at Athlit.

In 1912 the Straus Health Bureau was established, and Brünn and Goldberg began their investigation of malaria in Jerusalem. These workers examined children and adults from various sections of the city and found spleen rates among children varying from 40 to 83 per cent and a parasite rate among children and adults of 21.5 per cent. Mühlens in the same year reported parasite rates of 23 per cent among adults and 27 per cent among children.

During the World War all work stopped. The prevalence of malaria during this period was very high. Both armies as well as the civil population suffered severely. Among the British Expeditionary Forces 8,500 primary cases were reported, from April to October, 1918, in the front-line troops, while from October to the end of the year the number was over 20,000.

Records of malaria conditions on cessation of war activities are furnished by two surveys. These surveys were made in 1919, one by the medical officers of the Expeditionary Forces, the other by a Commission headed by Dr. Joffe. The former investigated conditions in the military camps, the latter those in the Jewish settlements. The military investigators classified the malaria conditions in the various camps as follows:

Intensely Malarious: Kishon Marshes, Haifa; Wadi Halim, Acre; Jordan Valley; Auja Valley in the Coastal Plain

Malarious: Samaleh; Nazareth; Haifa town; Lydda station; Suweleh village; Jerusalem city

Slightly Malarious: Acre camp; Haifa camp; El Afuleh; Nablus, Tul Karem; Ramleh; Es Salt, Beersheba

The Jewish Commission found malaria present in greater or lesser amounts in all the colonies. On the basis of spleen rates they classed the intensity of the malaria into five categories.

I. *Mild:* Mikweh Israel, Gedera, Beer Tuvia

II. *Moderate:* Metulla, Poria, Shfeyah, Rishon le Zion, Rehoboth, Ben Shemen

III. *Highly Malarious:* Rosh Pina, Yabniel, Sarona, Sejera, Zichron, Bath Shlomo, Kerkur, Petah Tikvah, Ekron, Artuf

IV and V. *Intensely Malarious:* Migdal, Kinnereth, Dagania, Menahemia, Beth Gan, Mesha, Merhavia, Athlit, Marah, Hedera, Gan Shmuel, Ein Ganim, Nahlat Yehuda

MALARIA INCIDENCE DURING THE POST-WAR PERIOD

Beginning with 1920 there is reliable information on the general prevalence of malaria from various sources. On the one hand there are annual reports of the Department of Health which, with the steadily improving reporting, constitute valuable sources of information. On the other hand there are the data of the special surveys and investigations conducted by the Malaria Research Unit and the Malaria Survey Section attached to the Department of Health.[1] In addition there is the large body of statistics from the chain of hospitals, laboratories, and clinics maintained by the Hadassah Medical Organization in the principal cities and settlements of Palestine.

The results of the blood and spleen examinations of the Jewish and Arab population in different parts of the country carried out

[1] The Malaria Research Unit was established by the American Joint Distribution Committee and the Malaria Survey Section by the International Health Board.

by the staff of the Malaria Research Unit, and of the special surveys of groups of villages made by the controller of the Malaria Survey Section, furnish a valuable indication or cross-section of the malaria conditions in the country at large. The complete morbidity data for the Jewish settlements gathered by the Malaria Research Unit during the last five years supplement these data and constitute important epidemiologic material.

INDICES OF MALARIA PREVALENCE

There are various ways of measuring malaria prevalence. These may be classified as subjective and objective. In the former category may be included morbidity data, histories of patients, physicians' records. Into the latter class fall spleen and blood rates. Which type of data yields the most reliable results depends entirely on the conditions. Under conditions prevailing among native populations in the Orient, histories and morbidity data are of little, if any, value. Only the patients with severe attacks of malaria visit a physician, and usually only a small percentage of these. Reporting is not practiced. Personal histories are vague. *Sukhne* may signify any kind of fever, and finer differentiation is hardly to be expected.

In this class of the population the objective tests yield the most trustworthy results. The blood and spleen indices, particularly the latter, furnish a reliable measure of the malaria endemicity in the Arab population. The Arab Fellah or Bedouin receives little, if any, treatment. A malaria infection once contracted persists for years and usually becomes chronic. The effect is registered by the pathologic enlargement of the spleen. The splenic enlargement, in general, and particularly that in children under twelve to fourteen years of age, is, therefore, a very satisfactory gauge of malaria endemicity.

A comparison of the blood and spleen indices may also furnish useful information on the epidemicity of the disease. The ratio of the blood to the spleen index or vice versa changes from season to season. It approaches unity during and shortly after an epidemic and diverges from unity during quiescent periods. During epidemics and for a short time thereafter the blood index is high and approximates the spleen index. After the epidemic has subsided, the parasites tend to disappear from the circulation while the splenic enlargement remains. This relation is strikingly illustrated in Table

XXV, which shows the ratios of the spleen to blood indices in a number of villages in the Huleh districts, examined first during May and again during August-September—before and after the epidemic season. The results are striking, except in the case of the Jewish villages, a phenomenon which will be discussed more fully here.

In the Jewish population the objective data offer no indication whatever of the prevalence of malaria. In this group of the population the blood and spleen rates even among children living in highly malarious areas are generally very low and, hence, deceptive with respect to the true malaria conditions. As practically all the Jewish settlements have good communal medical service the people receive

TABLE XXV

COMPARISON OF RATIOS OF SPLEEN AND BLOOD INDICES PRIOR AND SUBSEQUENT TO EPIDEMICS (1927)

(Ratio of Spleen to Blood Indices)

Time of Examinations	Melaha	Almenieh	Shed	Yessod (Jewish)	Tlell	Akhsania	Krad el Bagara	Wakas	Ayeleth (Jewish)	Krad el Ramani	Vasia	Mahanaim (Jewish)
20/5–... 3/6....	37/13 2.9	95/20 4.7	65/8 8.0	28/12 2.3	96/17 5.5	100/32 3.2	72/14 5.0	69/8 8.5	30/0	50/17 3.0	46/5 9.0	5/0 .....
23/8–... 10/9....	88/58 1.5	92/64 1.5	45/15 3.0	43/16 2.7	88/65 1.4	93/63 1.5	66/33 2.0	83/91 0.9	45/0	39/32 1.2	45/6 7.5	17/6 3.0

prompt, and at present also systematic, treatment. Consequently, a high malaria morbidity is not associated with a high spleen rate. The splenic index as usually employed is therefore of little value as a measure of malaria incidence among the Jewish population.

This lack of correspondence between the blood and spleen indices and malaria prevalence (endemic and epidemic) in the Jewish population is illustrated in Table XXV. Additional evidence is furnished by the accompanying data from settlements where malaria prevalence was known to be high. The tables show the blood and spleen indices in adjacent Jewish and Arab villages in which malaria was known to be equally prevalent. The data are for 1922 and 1923 when treatment, though prompt, was not always systematic. Equal divergence in results can be demonstrated today, as for example Yessod and Tlell, Ayeleth and Wakas in Table XXV.

The data are presented in three separate tables. The first shows the wide differences in the blood and spleen rates in adjacent Jewish and Arab villages subject to infection from the same source. The

TABLE XXVI

THE BLOOD AND SPLEEN RATES IN ADJACENT JEWISH AND ARAB VILLAGES WITH EQUALLY HIGH MALARIA PREVALENCE (1922-23)

Place	Number Examined			Number Positive			Per Cent Positive		
	Adults	Children	Total	Adults	Children	Total	Adults	Children	Total
					Blood Index				
Ekron:									
Jews	215	110	325	17	11	28	7.9	10.0	8.6
Arabs	52	139	191	6	42	48	11.5	30.3	25.1
Gedera:									
Jews	77	43	120	3	4	7	3.9	9.3	5.9
Arabs	2	46	48	0	5	5	0.0	10.9	10.4
Ein Ganim:									
Jews	255	118	373	10	6	16	3.9	5.1	4.3
Arabs	14	28	42	1	7	8	7.1	25.0	19.0
Merhavia:									
Jews	......	......	162	......	......	16	......	......	9.9
Arabs	......	......	185	......	......	54	......	......	29.2
Yessod:									
Jews	155	83	238	2	9	11	1.3	10.8	4.7
Arabs	36	38	74	3	9	12	8.4	23.7	16.2
Ayeleth:									
Jews	50	0	50	1	0	1	2.0	......	2.0
Arabs	13	13	26	1	3	4	7.7	23.0	15.4
					Spleen Index				
Ekron:									
Jews	160	85	245	14	8	22	8.7	9.4	9.0
Arabs	43	139	182	39	131	170	90.7	94.2	93.4
Gedera:									
Jews	73	38	111	27	14	41	37.0	36.8	36.9
Arabs	5	47	52	4	43	47	80.0	91.5	90.4
Ein Ganim:									
Jews	247	116	363	95	50	145	38.5	43.1	40.0
Arabs	14	28	42	14	27	41	100.0	96.4	97.6
Merhavia:									
Jews	95	32	127	24	4	28	25.3	12.5	22.0
Arabs	58	58	116	10	30	40	17.2	51.7	34.5
Yessod:									
Jews	155	83	238	55	28	83	35.5	33.7	34.9
Arabs	15	39	54	11	29	40	73.3	74.4	74.0
Ayeleth:									
Jews	50	......	50	3	......	3	6.0	......	6.0
Arabs	8	12	20	4	6	10	50.0	50.0	50.0

Jewish population in this group is composed of old settlers from fifteen to forty years in the country and not of recent arrivals.

Table XXVII shows the complete lack of correlation in Jewish villages between malaria prevalence and spleen rates in general and

TABLE XXVII

COMPARISON OF SPLEEN RATES WITH MALARIA INDICES IN JEWISH VILLAGES
(Malaria Incidence, 1922; Spleen Rate, March, 1923)

Place	Spleen Rates									Average Monthly Incidence Malaria (Per Cent)*
	Number Examined			Number Positive			Per Cent Positive			
	Adults	Children	Total	Adults	Children	Total	Adults	Children	Total	
Ekron	160	85	245	14	8	22	8.7	9.4	9.0	3.7
Gedera	73	38	111	27	14	41	37.0	36.8	36.9	6.7
Ein Ganim	247	116	363	95	50	145	38.5	43.1	40.0	8.5
Merhavia	95	32	127	24	4	28	25.3	12.5	22.0	11.9
Yessod	155	83	238	55	28	83	35.5	33.7	34.9	8.0
Ayeleth	50	0	50	3	0	3	6.0	......	6.0	8.5
Hedera	237	96	333	123	14	137	51.9	14.6	41.1	5.2

* The differences in results depend apparently on the effectiveness of treatment and frequency of recurrence of new infections.

the splenic index among the children under thirteen years of age in particular.

TABLE XXVIII

BLOOD AND SPLEEN INDICES AMONG DIFFERENT POPULATION GROUPS*

	Blood Index			Spleen Index		
	No. Examined	No. Positive	Per Cent	No. Examined	No. Positive	Per Cent
Jews	6,738	310	4.6	5,486	1,104	20.1
Arabs	1,746	219	12.5	1,220	763	62.5
Bedouins	616	83	13.5	385	226	58.8

* These figures represent the total findings during the general examinations of population groups prior to starting control in the various areas throughout the country. These examinations were made as a rule in March and April, before the epidemic season.

A still further illustration of this fact is shown in Table XXVIII, which summarizes the results of examinations of different population groups in known malarious areas. As seen from this table, both the blood and spleen rates are only one-third as high in the Jewish group as in the others. Nevertheless, the bulk of the Jewish rural

population, being relatively new and settled in the most malarious areas, suffers as much as, and usually much more than, their neighbors.

It is evident then that in Palestine one must use entirely different methods of ascertaining the prevalence of malaria among the different groups of the population. In the Arab villages and Bedouin encampments, the spleen index in children under thirteen years of age is as useful a criterion of malaria prevalence as it is in India or in any other country where treatment of patients is either absent or superficial and spasmodic. The relation of the blood to the spleen index and the degree of splenic enlargement may furnish

TABLE XXIX

BLOOD INFECTION AND SPLENIC ENLARGEMENT

Size of Spleen	Blood Infection		
	Number Examined	Number Positive	Per Cent Parasites
0	53	10	18.8
1	88	35	40.0
2	39	19	48.7
3	36	19	52.8
4	85	53	62.3

valuable data on epidemicity and intensity of infection. In the Jewish villages, where treatment is more regular and thorough, these indices are of little value and one must rely more on the so-called subjective data: the malaria history, the physician's reports, and, best of all, the actual morbidity data based in so far as possible on the blood examinations of patients.

The blood and spleen rates in Jewish settlements may have a certain limited value if the findings among adults and children or old adult settlers and recent adult immigrants are correlated. The experience during the last five years indicates that the following relationship may be deduced from such a comparison:

1. A continually high malaria incidence manifests itself by a much higher parasite rate among the children than among adults and an equal spleen rate among both adults and children.

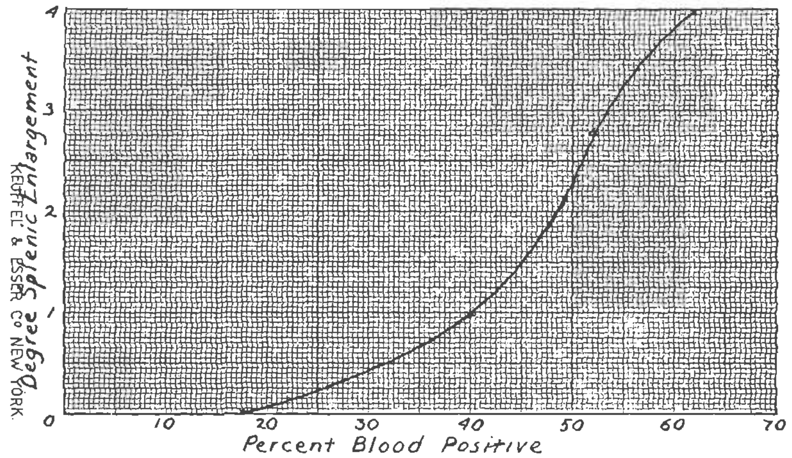
2. In an area where malaria has been prevalent and only recent-

ly brought under control, the blood rate is equally low and the spleen rate equally high among adults and children, or higher among adults according to the duration of the control period.

3. In a place where a year of low prevalence is followed by an epidemic, both the blood and spleen rates are higher among children than among adults.

These relations may serve as a general guide, but are by no means as reliable as are the blood and spleen indices in the native population.

CHART VI



Relation of Blood Infection to Splenic Enlargement

Even though the value of spleen indices varies in different communities, the determination of splenic enlargement is an important phase in the study of malaria. The enlargement of the spleen is a register of pathological change and often one finds rather striking correlations between degree of enlargement and blood infestation. Darling has already called attention to this type of correlation. Table XXIX and Chart VI present some interesting data obtained in studies in the Hedera region made with Dr. I. Weitzman. As seen from the table the percentage of blood infections increases with the increase in spleen size. The degree of splenic enlargement may, therefore, serve as a rough gauge of the number of carriers in a community.

DETERMINATION OF SPLENIC ENLARGEMENT

Different workers employ different methods in examining spleens. The one used by Darling is perhaps the most useful for comparative studies. We have not used Darling's method of weighting spleens according to size, but the general procedure has been similar to his.

FIG. 12.—Types of spleen among Bedouin children—horizontal type.

FIG. 13.—Types of spleen among Bedouin children—vertical type.

In order to detect the smaller degrees of enlargement, the person is placed in a reclining position with the knees flexed. This is particularly important with Arab children, because the abdomen is usually taut and resistant and palpation difficult. The clothing is removed and the abdomen exposed. In this position the spleen is palpated with slight pressure during inspiration and expiration. The degree of enlargement is designated as (1) palpable, (2) one finger, (3) halfway to the umbilicus, (4) greater degrees of enlargement. All spleens definitely palpable are considered enlarged.

Whatever the procedure adopted for ascertaining the splenic index, it is important that it be rigidly followed throughout the work. If possible the examinations should always be made by the same person. Unless this is done, the results are not comparable and consequently are of little value. The personal factor is such an important one and so much depends on the individual interpretation, particularly in cases of small degrees of enlargement, that comparable results are possible only when the same individual does all the examinations.

It is also important to carry out the examinations during the same period of the year. The size of the spleen is not constant. It varies with the number and severity of attacks and with the intervals between them. The spleen becomes enlarged during attacks, while after the attack the swelling slowly subsides. To obtain comparable data it is, therefore, necessary to make the examinations during the same period of the year. Our practice has been to carry out mass examinations during March and April. These months represent a period midway between the quiescent winter months and the summer and fall epidemics; new infections are rare, and the examination reveals exactly what we are looking for—the residual endemic index of malaria.

BLOOD EXAMINATION

In our blood examinations both the thick drop and thin smear are used. Drops and smear are taken from each individual on the same slide, the smear occupying about two-thirds and the drop one-third of the slide. In the laboratory the smears are fixed in bulk in alcohol by immersing only the lower two-thirds of the slide. After fixing the smears the entire slide is immersed in a 1:20 solution of Giemsa in boiled rain or distilled water having a pH 7.2–7.4 and left for thirty minutes. The drops are examined first, and whenever the diagnosis is doubtful the smear is also examined. This procedure combines the advantages of both the thick drop and smear without an appreciable loss in time or materials.

MORBIDITY DATA

No one can deny the superiority of the spleen index as a measure of malaria endemicity whenever it is applicable. It has the one su-

preme advantage that it provides objective information that any trained hand can detect.

When spleen rates do not yield correct information, as is the case in the Jewish population in Palestine, other methods have to be employed. Mortality rates are useless as an index of malaria prevalence, except perhaps where quinine is not available; but under these conditions the spleen index is much less subject to error. Under normal conditions in a malarious country, with medical aid and quinine

FIG. 14.—Spleen examination in the field

within easy reach of everybody, malaria is not a fatal disease, and the mortality is in no way indicative of the morbidity.

Under such conditions the only reliable measure of malaria prevalence is actual morbidity statistics. In most places this information is difficult to obtain because malaria is not a reportable disease. It is not an easy matter to enforce reporting of the important contagious diseases; compulsory reporting of malaria would prove even less successful, if for no other reason than that the general public is so accustomed to self-treatment that many never go to a physician unless the attack is acute.

In Palestine the situation in this respect, in the Jewish rural

communities, is quite unique. Every Jewish village has a community physician or a nurse. Most of the physicians have microscopes or, what is more important, are near enough to laboratories to avail themselves of their services. It was, therefore, only a matter of education and organization to obtain reliable statistics of malaria morbidity and of the prevailing types of malaria.

One of the first tasks of the Malaria Research Unit at the commencement of its activity was to organize regular, systematic weekly reporting of all malaria cases. Before work was started in a given section, the physician's records, the laboratory findings, if any were available, and the personal history of each inhabitant were obtained. In this manner it was possible to establish a composite and fairly reliable record of the malaria cases during a greater or lesser period prior to the commencement of the work. Thereafter, the local malaria inspector paid regular semiweekly or weekly visits to the doctors or nurses of each village or settlement and obtained from them the names of all the malaria patients and the records of the microscopic and clinical findings. These lists of names were checked by interviewing the patients and obtaining from them complete histories of their whereabouts two or three weeks prior to the illness, their previous attacks, etc. This personal contact of inspector and patient was also of the utmost educational value. In this way it was possible during 1922 and more effectively since then to gather accurate data of the malaria incidence in the Jewish villages.

MALARIA IN ARAB VILLAGES

Malaria conditions in 1920 in the Arab villages situated on or near wet wadis are indicated by the first report of the Department of Health.

> The villages situated on the wadis west of Hebron running from Beit Jibrin in the Judean Hills to the Plain of Philistia were particularly affected (by malaria). Few persons in this region escaped the disease. . . . . The death rate in this region during the latter part of 1920 was 68 per 1,000, the mortality being particularly high among infants and young children. In the village of Beit Jibrin itself, one sixth of the population died in three months.

The conditions as described above were perhaps extreme. They illustrate, however, the inroads made by the disease in villages situated near an anopheles breeding-source. Other villages in various

parts of the country (Naaneh, Cherkas, Harbaj, Solim, Tel Fir, for example) suffered as much, but the records there are not so complete.

In similarly located villages where no control work has been carried on, the malaria prevalence is practically as high today as it was in 1921. This is shown by the repeated blood and spleen examinations made by the staff of the Malaria Research Unit from year to year in villages not affected by the malaria control-work. The results of some of these examinations are summarized in Tables

TABLE XXX

COMPARISON OF AVERAGES OF BLOOD AND SPLEEN RATES IN SUCCESSIVE YEARS SINCE 1921 IN VILLAGES LOCATED IN AREAS NOT UNDER CONTROL AT THE TIME OF THE EXAMINATIONS

Date of Examination	Blood			Spleen		
	No. *Examined*	No. *Positive*	Per Cent *Positive*	No. *Examined*	No. *Positive*	Per Cent *Positive*
1921 May–June..	141	12	8.5	128	93	72.6
1922 March......	343	49	14.2	275	186	67.6
1923 March–April	659	136	20.5	354	271	76.5
1924 March–April	115	13	11.3	112	78	69.6
1925 March–April	209	41	19.6	157	97	61.8
1925 June........	128	28	21.8	78	47	60.2
Average.....	1,595	279	17.5	1,104	772	69.9

NOTE.—The figures for 1921 and 1922 are for total population (adults and children), those for late years are for children under thirteen.

XXX and XXXI. The first gives a summary of the results of the examinations year after year in different villages located in malarious zones. The second presents in detail the results of examinations made in 1925. The first shows clearly that where conditions favoring anopheles-breeding exist, the amount of infection at present, as indicated by the blood and spleen indices, is about the same as five years ago. The second shows that in this regard conditions do not vary materially in different sections of the country.

The explosive character of the disease and the unusually high mortality have apparently subsided with an improvement of economic and nutritive conditions, but the amount of infection has remained quite constant. This is important in the light of the statements made repeatedly that the disease regresses spontaneously with the improve-

ment of economic conditions. Such may be the case in a highly cultivated country temporarily neglected as a result of war, famine, or similar catastrophe. Under such conditions improvement of eco-

TABLE XXXI

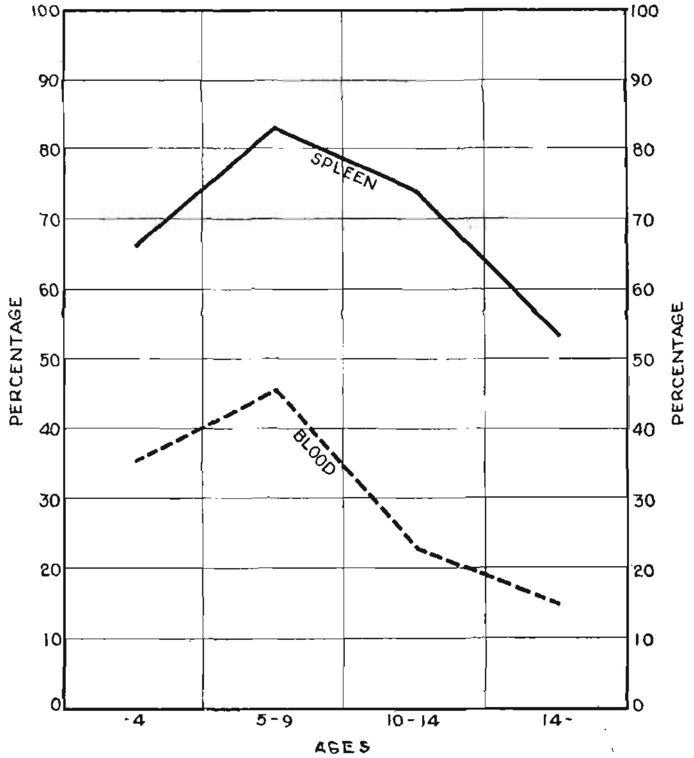
Blood and Spleen Rates for 1925 (Examinations Made in March and April) in Villages in Areas Not Under Control

Village	Blood						Spleen		
	Adults			Children			Children		
	No. Exam.	No. Pos.	Per Cent Pos.	No. Exam.	No. Pos.	Per Cent Pos.	No. Exam.	No. Pos.	Per Cent Pos.
Kishon Valley:									
Hartieh	11	3	27.0	......	......	......	6	4	66.7
Sheikh Abreik	16	3	19.0	12	3	25.0	10	6	60.0
Harbaj	......	......	......	18	3	16.5	18	12	66.6
Total	27	6	22.2	30	6	20.0	34	22	64.7
Acre Plain:									
Jidru	......	......	......	44	12	27.3	43	25	60.4
Coastal Plain:									
Tantura	......	......	......	86	8	9.3	87	41	47.1
Hassan Said	23	7	30.0	34	4	10.2	10	8	80.0
Foukra	29	3	10.3	40	4	10.0	27	18	66.6
Cherkas	21	3	14.3	15	8	53.3	14	10	71.4
Dameira	......	......	......	46	14	30.4	46	23	50.0
Abu Jemain	......	......	......	6	1	16.7	6	3	50.0
Total	73	13	17.8	141	31	22.0	103	62	60.2
Judea:									
Nahr Sorek	......	......	......	......	......	......	5	3	60.0
Seged	16	1	6.2	11	1	9.0	11	8	73.0
Rafat	......	......	......	......	......	......	6	5	83.3
Jordan:									
Jissr	13	2	15.4	10	3	30.0	8	4	50.0
Beisan Plain:									
Sakhneh	29	3	10.3	11	3	27.2	11	9	81.8

nomic conditions implies elimination or restriction of anopheles as well as of carriers of plasmodia, particularly the latter. In a primitive, poorly developed, semi-tropical country such as Palestine, there may be a reduction in the severity of the disease, but there does not seem to be any spontaneous regression in so far as the amount of infection is concerned. Without human interference the elimina-

tion or even checking of the disease is apparently not feasible. This important question will be discussed at greater length elsewhere.

CHART VII



Splenic Enlargement and Blood Infection in Different Age Groups

AGE AND SEX DISTRIBUTION

The *age* and *sex* distribution of the infection is the same as in other malarious countries. The highest parasite and spleen rates are found in children during the first ten years of life. After that there is a progressive reduction. Males and females seem equally affected. In some villages the infection is higher among male children owing to their greater exposure in fields in the vicinity of swamps remote from the village. Many villages cultivate fields some distance away and the inhabitants camp there, particularly during harvest time. The data in Tables XXXII and XXXIII are typical. They contain

TABLE XXXII

Age Distribution of Infection

Village	0–4 Years					5–9 Years					10–14 Years					15–19 Years					20–29 Years					30+ Years				
	Blood			Spleen		Blood			Spleen		Blood			Spleen		Blood			Spleen		Blood			Spleen		Blood			Spleen	
	No. Ex.	No. +	% +	No. +	% +	No. Ex.	No. +	% +	No. +	% +	No. Ex.	No. +	% +	No. +	% +	No. +	No. +	% +	No. +	% +	No. +	No. +	% +	No. +	% +	No. +	No. +	% +	No. +	% +
Cherkas 29/12/25	17	14	*82*	15	*88*	10	9	*90*	10	*100*	10	5	*50*	8	*80*	10	3	*30*	*7 10	*70*	6	0	0	1 3	*33*	21	6	*29*	9 12	*75*
Birket Batikh 7/1/26	22	19	*86*	20	*91*	7	2	*29*	7	*100*	7	1	*14*	5	*71*	7	2	*29*	4 7	*57*	13	2	*15*	3 11	*27*	22	4	*18*	8 14	*57*
Damaira 13/1/26	22	15	*68*	17	*77*	12	4	*33*	11	*91*	7	1	*17*	5	*83*	12	0	0	2 9	*22*	11	2	*18*	4 6	*66*	20	0	0	4 11	*36*
Baika 24/2/26	43	13	*30*	30	*70*	20	5	*25*	16	*80*	20	4	*20*	13	*65*	48	6	*13*	15 32	*47*	42	0	0	12 24	*50*	77	4	*15*	15 49	*30*
Hassan Said 10/3/26	43	19	*44*	29	*67*	28	12	*43*	23	*82*	39	5	*13*	24	*61*	40	4	*10*	12 28	*43*	52	0	0	8 22	*25*	69	3	*4*	9 34	*26*
Foukra 20/3/26	23	12	*52*	16	*68*	17	9	*53*	15	*88*	17	3	*18*	12	*70*	26	1	*4*	7 17	*41*	34	1	*3*	6 16	*38*	49	0	0	6 27	*22*
Atta 21/3/26	8	6	*75*	8	*100*	7	3	*43*	7	*100*	6	2	*33*	5	*83*	8	1	*12*	2 6	*33*	5	1	*20*	1 2	*50*	17	0	0	1 8	*12*
Total	178	98	*55*	135	*76*	101	44	*44*	89	*88*	105	21	*20*	72	*68*	151	17	*11*	49 109	*45*	163	6	*31*	35 84	*37*	275	17	*6*	52 155	*34*

* The number beneath the line is the total examined; only the adult women who had severe malaria allowed themselves to be examined.

the results of examinations made during 1926 in a group of villages near Hedera. Similar results were obtained in other regions.

TABLE XXXIII

AGE AND SEX DISTRIBUTION OF BLOOD AND SPLEEN RATES IN A HIGHLY ENDEMIC AREA

Place	Male						Female				
	Age	No. Examined	Blood +	Per Cent +	Spleen +	Per Cent +	No. Examined	Blood +	Per Cent +	Spleen +	Per Cent +
Cherkas	0–14.....	20	16	80	18	90	21	15	71	19	80.5
	Adults...	18	2	11	13	72	15	1	6	.....	.....
Batikh	0–14.....	23	16	70	21	91	13	6	46	11	86
	Adults...	19	3	16	11	58	23	5	22	.....	.....
Damaira	0–14.....	22	13	59	18	82	18	7	39	15	83
	Adults...	24	0	0	8	33	19	2	10	.....	.....
Baika	0–14.....	48	13	27	34	71	36	9	25	26	72
	Adults...	82	4	5	33	40	85	6	7	.....	.....
Hassan Said	0–14.....	61	19	31	43	70	50	17	34	39	78
	Adults...	87	2	2	25	28	73	5	7	.....	.....
Foukra	0–14.....	29	10	34	22	77	32	15	47	25	78
	Adults...	56	1	2	19	34	53	1	2	.....	.....
Atta	0–14.....	9	5	55	9	100	13	6	46	12	92
	Adults...	17	1	6	4	23	12	1	8	.....	.....
Total	0–14.....	212	92	43.4	165	77.8	183	75	41.	147	80
	Adults...	303	13	4.3	113	37.2	280	21	7.5	.....	.....

MALARIA IN THE JEWISH SETTLEMENTS

For various reasons the Jewish settlements, with rare exceptions, are situated in highly malarious regions. The swampy lands were least settled and most readily bought. These lands were also desirable, because they were the best watered and consequently the best suited for agriculture. The agricultural lands lie in the plain, and the Jew did not, like his Arab neighbor, live in the hills and descend to the plain to cultivate his lands. As a result of these various factors the Jewish settlements are, as a rule, to be found near water-courses and marshes where anopheles abound. This, coupled with the fact that the Jews were new to the land and hence wholly nonresistant to infection, created a condition which was almost, if not quite, disastrous.

With perhaps two exceptions the Jewish settlements are all situated in what used to be highly malarious areas. The result was re-

flected in the malaria incidence at the time control work began. Table XXXIV presents a summary of the morbidity data in various

TABLE XXXIV

INCIDENCE OF MALARIA IN THE JEWISH SETTLEMENTS PRIOR TO CONTROL

(Mean monthly incidence of malaria per thousand population the year the survey was made preparatory to control)

Place	Year	Incidence
Ayeleth	1922	103
Yabniel	1920	185
Jordan settlements	1920	94
Menahemia	1921	55
Ein Harod	1922	117
Kfar Yehezkel	1922	58
Tel Yoseph	1922	99
Beth Alfa	1922	355
Merhavia	1922	179
Nahalal	1922	92
Benjamina	1922	91
Athlit	1922	203
Hedera	1922	74
Gan Shmuel	1922	111
Nahlat Yehuda	1921	130
Ekron	1921	140
Hulda	1922	68
Petah Tikvah	1921	225
Ein Ganim	1921	85
Mahneh Yehuda	1921	140

TABLE XXXV

MALARIA RISK TO NEW IMMIGRANTS DURING THEIR FIRST YEAR IN THE COUNTRY—1921

Place	Six Months or Less in Country			Six Months to One Year		
	No. Exam.	No. Contracted Malaria	Per Cent	No. Exam.	No. Contracted Malaria	Per Cent
Migdal	67	12	18.0	23	12	52.0
Beth Shan	6	5	83.3	3	3	100.0
Haifa Jedda	59	37	62.8	23	17	74.0
Afuleh	38	17	44.7	19	12	63.2
Total	170	71	42.0	68	44	64.7

settlements in different parts of the country prior to commencement of control.

Another indication of the prevalence of malaria among Jewish settlers is given by the incidence of malaria in groups of new settlers in 1921 (see Table XXXV). Groups of immigrants less than one year in the country living in various camps were examined and their malaria history ascertained. The results showed that 42 per cent developed malaria during the first six months of their stay and 64.7 per cent during the first year. These data indicate the extent of the danger to which the new settlers were exposed on their arrival in Palestine.

TYPES OF MALARIA

The prevailing types of malaria are benign and malignant tertian. Quartan malaria presents a peculiar condition. In general ex-

TABLE XXXVI

RELATIVE INCIDENCE OF P. VIVAX, P. FALCIPARUM, AND P. MALARIAE IN MASS EXAMINATIONS

(Percentages of Total Positive Findings)

Locality	P. vivax	P. falciparum	P. malariae	Time of Examination
Cherkas-Dameira (Samaria)	33.3	53.2	13.4	December–January
Akhsania (Huleh)..........	12.5	37.5	50.0	June
Krad er Romani (Huleh)..	66.7	11.1	22.2	June
Krad el Bagari (Huleh)....	66.6	33.3	0.0	June
Vagas (Huleh)............	50.0	50.0	0.0	June
Vazia (Huleh)...........	50.0	50.0	0.0	June

aminations of native groups of population the percentage of quartan infections is often unusually high. And yet cases of quartan malaria are rarely encountered in the course of the general routine examinations in laboratories. In all our case records quartan malaria constitutes only a fraction of 1 per cent of the total malaria.

Typical findings in mass examinations of population groups in different sections of the country are summarized in Table XXXVI. The results vary considerably in different localities and even in different villages in the same locality. It is clear, however, that there are isolated foci where quartan malaria is quite common.

The reason for the restriction of quartan malaria and its failure to extend to the general population is not clear. But the practically complete absence of quartan infections during the epidemic periods

is strikingly shown by Table XXXVII, summarizing the results of the examinations in different laboratories of the country during the years 1922, 1923, and 1924.[1] Among 13,711 positive films only 216, or 1.6 per cent, were *P. malariae*. These results also contain the positive findings in the course of some of the mass examinations.

TABLE XXXVII

RELATIVE FREQUENCY OF DIFFERENT TYPES OF MALARIA
(AS SHOWN BY LABORATORY RETURNS FOR THE YEARS 1922–24)

Type of Malaria	No. of Positive Findings	Relative Percentage
Benign tertian	9,478	69.13
Malignant tertian	4,017	29.30
Quartan	216	1.57
Total	13,711	100.00

The same table also indicates the relative frequency of *P. vivax* and *P. falciparum*. The ratio shown in the table is about 5 to 2. But this is only generally true. In the epidemic years before active control work was started, the relative percentage of *P. falciparum* was much higher. In 1922, for example, the laboratory findings were those given in Table XXXVIII.

TABLE XXXVIII

	No. Positive	Percentage of Total Positive
P. vivax	3,374	58.6
P. falciparum	2,319	40.3
P. malariae	61	1.1

These figures are more nearly representative of the relative frequency of benign and malignant tertian malaria during epidemics for the country as a whole. They fail, however, to give a true picture of the condition prevailing in the country because the conditions in the Coastal Plain are entirely different from those in the inland plains. In the Coastal Plain nearly 80 per cent of the malaria is benign tertian, while in the inland regions the two are equally preva-

[1] These figures were prepared by Dr. G. Stuart of the Department of Health.

lent, now one, now the other being dominant according to season and year.

SEASONAL PREVALENCE

The two forms of malaria not only have a different spatial distribution, but their seasonal prevalence is quite distinct. There is a well-defined seasonal periodicity in the occurrence of the two types of malaria. Benign tertian malaria occurs in large numbers during the spring months when malignant tertian malaria is extremely rare. A severe fall epidemic of malignant tertian malaria is followed by a large increase in the numbers of benign tertian cases during the late winter and early spring months. Epidemic outbreaks of benign tertian malaria follow during the months of June, July, and August.

TABLE XXXIX

MONTHLY FREQUENCY OF DIFFERENT TYPES OF MALARIA AS SHOWN BY LABORATORY RETURNS

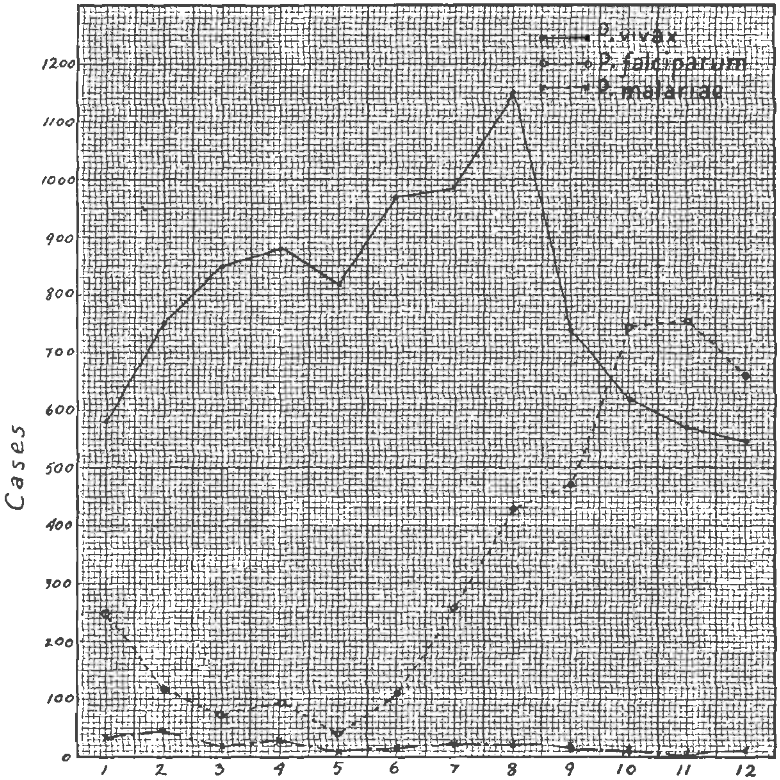
Type of Malaria	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Benign tertian.....	581	757	847	879	822	971	987	1,150	742	622	573	547	9,478
Malignant tertian..	249	119	72	94	43	114	258	429	476	745	761	657	4,017
Quartan..........	26	45	23	31	6	8	20	22	8	10	5	12	216
Total........	856	921	942	1,004	871	1,093	1,265	1,601	1,226	1,377	1,339	1,216	13,711

Malignant tertian malaria, on the other hand, occurs rarely during these months but the incidence of cases rises sharply late in the summer, and epidemic outbreaks invariably occur during the months of October and November. The distribution of the various forms of malaria throughout the year is shown in Table XXXIX, summarizing the results of laboratory findings. This table does not represent cases, nor does it differentiate primary from secondary cases. It is only a summary of positive laboratory findings and shows in a general way the relative frequency of the different forms of malaria throughout the year.

The same results are shown graphically in the accompanying chart. It will be noted that there are three distinct periods. The first, covering the months of February to June, consists almost entirely of benign tertian malaria. The second period extends from the middle of June to the middle of August and consists chiefly of benign tertian, with a moderate number of cases of the malignant tertian,

or tropical, malaria. In the third period, the last three months of the year, there is a sharp rise in the cases of malignant tertian, with a proportional fall in the incidence of the benign tertian form of the disease. Quartan malaria is rare, but is more common, if present at

CHART VIII



Monthly Prevalence of the Different Types of Malaria

all, during the winter months of the year, some of them undoubtedly derived from general examinations of population groups. This seasonal prevalence of the different types of malaria corresponds closely with that reported by Wenyon for Macedonia.

RELAPSES AND PRIMARY INFECTIONS

The foregoing figures do not differentiate primary and secondary infections. Such a distinction between relapses and primary

infections is essential in studying the prevalence and seasonal distribution of the various forms of malaria. It is, of course, exceedingly difficult to differentiate primary infections from relapses; but without such a differentiation it is not possible to follow the epidemicity of the disease. As in the case of other statistical classifications, it is necessary to adopt some rule, to some extent arbitrary, which serves as a basis. First attacks in children or newcomers naturally offer no difficulty. Patients who have had previous attacks are not easily differentiated. The following rules have proved extremely helpful in our work:

1. Any attack during the summer and fall *more than one year* after the previous attack was considered a *new infection.*

TABLE XL

MEAN MEDIAN MONTHLY INCIDENCE OF RELAPSES IN PERCENTAGE OF TOTAL POPULATION

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Benign tertian...	3.1	3.6	4.2	5.0	3.9	4.0	4.8	4.2	4.0	3.4	3.8	3.8
Malignant tertian...	0.7	0.7	0.4	0.6	0.3	0.5	1.1	1.1	0.7	1.0	1.1	1.0

2. An attack of malignant tertian malaria after one of benign tertian was also classed as a *new infection.*

3. An attack in the winter and early spring subsequent to an attack the previous summer or fall was classified as a *relapse.*

4. All recurrent infections less than one year after the previous attack were also considered as *relapses.*

This classification is undoubtedly subject to error. The error, however, is not additive. The best test of any arbitrary set of rules is their practical usefulness, and this has been amply furnished by our experience during the last five years. This classification invariably enabled us to see the approach of an epidemic and often in time to take measures to prevent or to check it.

The morbidity data accumulated on the basis of the foregoing classification give a better picture of the endemic and epidemic character of the disease than can possibly be obtained from spleen rates or from the laboratory blood findings presented above.

Relapses.—Relapses occur more or less constantly throughout

the year. As a rule, however, the number of secondary cases during December, January, and February is relatively small. In March or April, according to the year, there is a sudden rise followed by a drop in May. During the rest of the year the curve of relapses remains fairly uniform. The data are presented in Table XL.

The great majority of the relapses consist of benign tertian malaria. This is due chiefly, of course, to the great resistance of this form of malaria to quinine treatment. But of special interest is the rise of relapses in March or April. The reason for this phenomenon is still obscure, but it is a fairly constant occurrence.

In contradistinction to benign tertian relapses, those of malignant tertian malaria are at a minimum during March, April, and May. The number increases abruptly in July and continues at about the same level for the rest of the year. This seasonal difference between the two forms of malaria is even more striking in the primary cases.

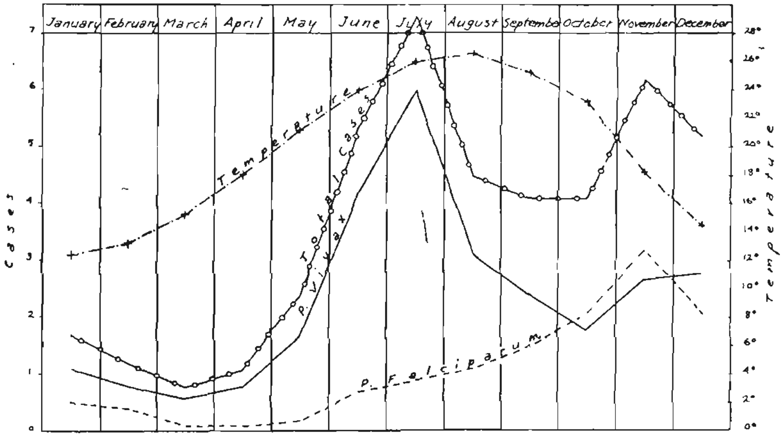
Primary infections.—Primary infections also occur throughout the year but there are two sharply defined epidemic seasons. One epidemic occurs in June–July, the other in October–November. The former, or summer, outbreak begins usually in the latter half of June and lasts to the middle of August. Then there is a lull until the latter half of October, when the fall epidemic begins. This reaches its peak during the latter part of November, and continues to the middle or end of December.

The accompanying chart presents the picture of the trend or course of primary infections throughout the year. The curve shows the average distribution of the two main types of malaria for the years 1923 to 1925. It is a generalized curve based on the average for the three years, and shows the annual course of primary infections in the country as a whole.

The difference in the seasonal distribution of primary and secondary infections is clearly indicated in Table XL and Chart IX. Primary infections depend on the activity of the anopheles vectors and consequently occur during those periods of the year when they are most active. Secondary infections or relapses depend chiefly on unknown factors associated with host resistance, the effect of quinine on the parasites, quality and extent of treatment, etc. The bulk of

the summer and fall malaria consists, therefore, of primary infections, while the winter and spring malaria consists chiefly of relapses. This does not mean that primary infections do not occur during the winter and spring months. As indicated in the preceding chapter there is no true hibernation in Palestine; there is, however, a cessation of breeding and a sufficient inhibition of adult activity to render primary winter infections infrequent. These facts are reflected in the results depicted in the chart; primary infections occur but they are uncommon.

CHART IX



SEASONAL OCCURRENCE OF PRIMARY CASES OF *P. vivax* AND *P. falciparum*

SEASONAL DISTRIBUTION OF MALIGNANT AND BENIGN TERTIAN MALARIA

Reference has already been made to the peculiar seasonal prevalence of the two principal types of malaria, whether secondary or primary. Benign tertian malaria is pre-eminently a spring and summer disease. Relapses occur during the winter and spring, and epidemics during the summer months. It is a cold-season infection.

In contradistinction, the malignant tertian type of malaria occurs rarely in the winter and spring. Occasional cases begin to appear in the summer. Slowly the number increases until the end of September or early October, when there occurs an explosive increase in cases, which grow rapidly, reaching a peak late in October

or early in November, and then fall as rapidly, giving the picture of a sharp curve.

Relapses of tropical malaria begin to increase during the summer. Celli and Mühlens record relapses of malignant tertian during the summer in places where new infections could be definitely excluded. In malarious areas, these relapses are apt to be overlooked, because they come during the time when new infections are possible. But these relapses are presumably the precursor of the malignant epidemic in the fall. Without such relapses, it would be difficult to account for the source of the parasites in the fall epidemic.

What is the reason for this rhythm in benign and malignant tertian malaria? This is one of the problems of malaria epidemiology that is still obscure. This periodicity is observed in other diseases. The epidemicity of typhoid and dysentery in Palestine parallels that of malaria rather closely. The relation of season to host susceptibility is a problem only now being approached experimentally. The elucidation of the problem of seasonal prevalence of the two types of malaria is one of the tasks of the malariologist.

CHAPTER VI

GENERAL CONSIDERATIONS OF THE EPIDEMIOLOGY OF MALARIA IN PALESTINE

Despite the fact that malaria is an old and well-known disease, there are many factors in its epidemiology which are still obscure. In considering the epidemiology of malaria, it is necessary to examine two sets of variables, the one centering around the human host, the other around the intermediate host, the mosquito. But in addition to the factors responsible for the differences in host resistance and variations in vector prevalence, many of which are still but little understood, there are a number of significant variables of a social character which may easily be overlooked.

In considering the question of the epidemiology of malaria, it is therefore necessary first of all to analyze and evaluate all of the factors concerned in the maintenance and distribution of the disease. In other words, we must have a clear idea of the endemic, as well as the epidemic, character of the disease in the particular locality studied.

The analysis of the epidemiology of malaria involves, therefore, a study of four sets of factors:

1. The variables of a social-economic character.
2. The variables in host susceptibility.
3. The variables centering about the insect vector.
4. The variables in relation to the parasite.

THE SOCIAL FACTORS

The importance of the social factor in the epidemiology of malaria is strikingly demonstrated in Palestine. We have here a paradoxical situation. In the two groups of people living side by side, there is a high epidemicity and a low endemicity in one and the reverse, a high endemicity and low epidemicity, in the other. While this situation introduces certain complications in the study of the problem, it throws light on some of the general phases of the question which are particularly under discussion today. As was pointed

out in the preceding chapter, highly malarious Jewish villages, such as Hedera, Gan Shmuel, and Yessod, have blood and spleen rates so low as to indicate a very low endemicity, while the neighboring Arab villages, exposed to the same conditions, give histories of a lower infection rate (actual figures are out of the question) and have a blood and spleen rate indicative of a very high malaria endemicity. Evidently, there are some variables not apparent at first sight.

A knowledge of the social conditions in these two groups of villages clarifies the paradoxical condition mentioned. The Jewish agricultural population are intellectually, socially, and economically on a higher level than their Arab neighbors. The former are recent city-dwellers (the oldest among them were city-dwellers forty and the youngest two or three years ago), and have retained some of the requirements of the city-dweller. They live in close communities, have a physician at hand either in their own settlement or, if that is too small, in the one close by. They also have their teacher for kindergarten and primary school. But along with this they are in the main more or less recent immigrants unaccustomed to the hardships and strain of agricultural life. These people are, therefore, on the one hand, more susceptible to infection and open to epidemic outbreaks while, on the other, being of a higher intellectual level, they readily seek medical aid. Consequently, treatment is prompt and effective, and the endemicity remains low. The Arab peasants, however, have lived in their present condition for generations, if not centuries. They have no physician, and seek none except in extreme cases. The intellectual level is low, and they consider illness a decree from heaven and death the will of Allah. However, in addition to a slowly acquired immunity, as a result of infection early in life, they are hardened to their condition of life, and have a higher native resistance than their Jewish neighbors; many of them are found to have parasites in the blood without acute manifestations of illness. The chronic character of the infection accounts for the high endemicity and apparently low epidemicity.

Movement of population groups.—Another point that may be difficult to understand at first sight is how in a country as sparsely settled as Palestine the disease is so widely spread and epidemics so continuous. Epidemics are usually correlated with crowding. Again

the answer is furnished by a study of the social and economic conditions prevailing here. Because the country is small and undeveloped, there is a constant active movement of the various population groups. And this movement is as effective in spreading malaria and maintaining its epidemicity as it would be in the case of any other infectious disease.

There are three population groups whose movements must be considered. First in importance is the Bedouin. This class of people is still in the pastoral stage of civilization. There are between 70,000 and 100,000 of them in Palestine. The majority of these people have no fixed abode. In the spring they spread over the country with their flocks; coming from the south and east, they literally invade the country and take up their abode on any uncultivated plot favorable for pasture and near water. The infection rate among them is extremely high—in some cases 100 per cent. They thus constitute a constantly moving focus of malarial parasites. This movement is particularly marked when the south and east suffer from drought as was the case in 1926.

As against this movement, there is the counter-movement of the non-immune immigrant population settling on hitherto uncultivated lands, traveling over the country in search of work or of a place to strike root. Along the coast, these new immigrants come in contact with the semipermanent type of Bedouin dwelling in or near a marsh (Nahr Rubin, Ramadan, Khudeireh, Kabbara). In the Valley of Esdraelon or Galilee, they meet the fully nomadic type. In any case they come in contact with an ever menacing source of infection, whether that source be the nomad or seminomad Bedouin or the highly infected Fellah.

Another movement of importance is the annual pilgrimage to the genuine or spurious tomb of a prophet. There are several, the most important from a malaria standpoint being the one at Nebi Rubin. This shrine is supposed to mark the burial place of Reuben, the eldest son of Jacob. It is located along one of the coastal marshes. Thither every year tens of thousands of devotees come and stay in tents for greater or lesser periods. Here thousands are infected with malaria, with which they return to their native villages. In 1924, it was estimated that ten thousand people were infected—a guess, but

probably a fair one. In 1925, the number seemed to be considerably less. The reason was not apparent, but a clue is provided by the fact that in 1924 the festival fell in August, while in 1925 it took place in September. This is significant as will be seen later when the relation of the anopheles vectors to the epidemicity of malaria is discussed. The type of anopheles here is *A. elutus*, whose activity decreases progressively during August and practically ceases in September.

It is evident then that the habits of the people and the social and economic conditions of the country greatly affect the endemicity and the epidemicity of the disease and its peculiar local characteristics.

VARIATIONS IN HOST RESISTANCE

The variations in host susceptibility and resistance are but little understood. It is commonly agreed that individuals subjected to repeated attacks develop a resistance against new infections. The nature and duration of this resistance is still obscure. Parallel studies carried out by us on animals infected with trypanosomes indicate that the resistance is cellular in character and that its duration after a cure is approximately five months. It is likely that the nature of the resistance in man is similar in character although, after repeated attacks, perhaps of longer duration.

Another as yet obscure factor of importance is the relation of diet and nutrition to host susceptibility. Again in experimental infections with trypanosomes we have found that diet has a profound influence on the course of the infection and survival time of infected animals. The relation of nutrition to human susceptibility to malaria still remains to be determined.

The relation of these factors of host susceptibility and resistance to the epidemicity of malaria has received little attention from malariologists. Yet its importance can hardly be questioned. Epidemiologic observations have forced to our attention time and again the significance of this factor. In one new settlement, in 1924, there developed a series of cases. Mosquito control was satisfactory. Careful search revealed only a rare specimen of *A. elutus*. Yet among these recent arrivals unaccustomed to the hardships of their new life these isolated anopheles were sufficient to cause a small

epidemic. In the course of our work here we have had other experiences different in character but demonstrating the importance of host susceptibility. One village, Bet Alfa in the Valley of Esdraelon, is now relatively free from malaria. There are always a few anopheles filtering in from the adjacent uncontrolled area. This year (1927) 65 workers were transferred there from the city toward the end of September. During October 35 of them developed malaria, although there were only four cases among the 240 people of the settlement. Allowing for greater risk and exposure, the difference is striking. Still a different type of experience is the effectiveness of treatment in different groups. In one demonstration area careful observations were made on the effect of quinine treatment on various groups of population. One group was a well-established settlement, the other was a labor camp. The method of treatment and supervision was the same; the Bass standard treatment was used. The percentage of patients relapsing during the treatment or within six months thereafter was nearly twice as high in the labor group as in the settlement.

It is apparent to what extent host susceptibility may affect or modify the epidemicity of malaria. Unfortunately, this phase of the subject has hitherto received but scant attention. The relative ease with which experimental malaria in paretics is reported to be cured in contrast to the difficulty experienced in curing cases of natural infections is another illustration of the important part played by the host. Cure of malaria is due at least as much to the host as to the quinine. The problem of host susceptibility and resistance calls for further study.

THE ANOPHELINE HOST

The third set of variables playing a highly important rôle in the epidemiology of malaria is that relating to the intermediate host. Although there are numerous observations on the anopheles mosquitoes, their relative infectivity, etc., there are still many lacunae in our knowledge of the bionomics of these insects and the conditions favoring their infection and the transmission of the disease. Without a full knowledge of the habits of the mosquito vector, it is not possible to obtain a clear understanding of the epidemiology of the disease. In Palestine as elsewhere malaria is a seasonal disease. But

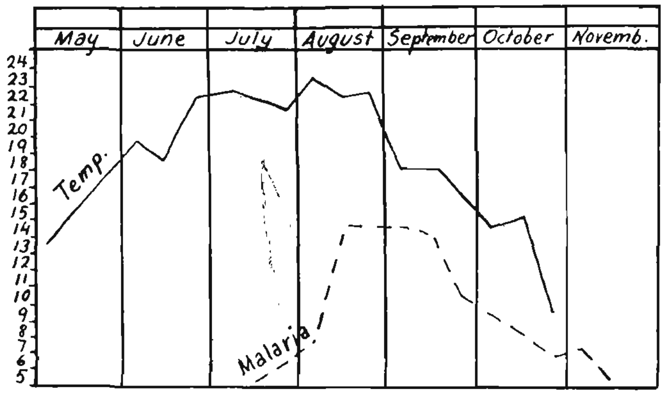
unlike in Italy or the United States, malaria here has two distinct epidemic periods, one in June–July–August with the peak in July, the other in October–November–December.

The reason for this phenomenon remains obscure without a knowledge of the bionomics of the local vectors. Our studies have led us to conclude that the particular time of the epidemic outbreak depends on the prevalence of the vector, which in turn is regulated chiefly by the temperature. In Palestine, as pointed out before, there are three important natural vectors of malaria, *A. elutus*, *M. superpictus*, and *M. sergenti*. A study of the habits of these mosquitoes has shown that the first has two seasons of high activity, with a period of depression extending from the middle of August to the middle of October; the last has only one period of high activity, in September and October. *A. elutus* has peaks in June and November, and that accounts for the epidemic outbreaks in June–July–August and the middle of November and December, respectively. *M. superpictus* and *M. sergenti* have their period of maximum development in September–October, and this accounts for the fall epidemics starting in October.

It appears fairly certain that the activity of these species is regulated by the temperature. Consequently, the occurrence of epidemics at a particular season of the year depends primarily on the existence at that time of the particular temperature favorable to the active development of the local anopheles vector. If in a given year the temperature is unfavorable (too high or too low), the extent of the epidemic will register the difference. Similarly, in countries where the favorable temperatures exist during other months the epidemic season will also be shifted. Thus, in Italy the favorable temperature for the development of *A. maculipennis*, the important vector, occurs in June–July–August and the epidemic season is August–September. In Palestine this is the lull period between the two epidemic seasons, because it is too hot for the development of the local vectors. A similar condition is noted in the curve reproduced in Chart X showing the relation of malaria to temperature in Rumania. The peak is in August–September when the mean temperature is $22°$–$23°$ C., the same as that prevailing in June and October in Palestine.

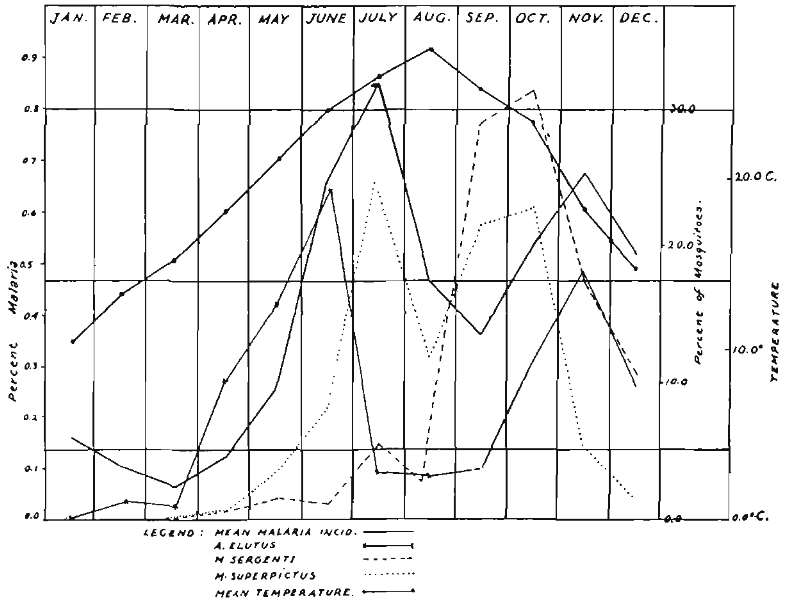
We do not have the data on the maximum monthly prevalence of *A. maculipennis* in Rumania but we have accurate data on the

CHART X



Temperature and Malaria in Rumania

CHART XI



Relation of Temperature, Anopheline Prevalence, and Malaria Incidence

prevalence of the Palestinian anopheles vectors compiled over a period of several years. The accompanying chart shows the close relation between the general epidemic curve and the curves of vector prevalence.

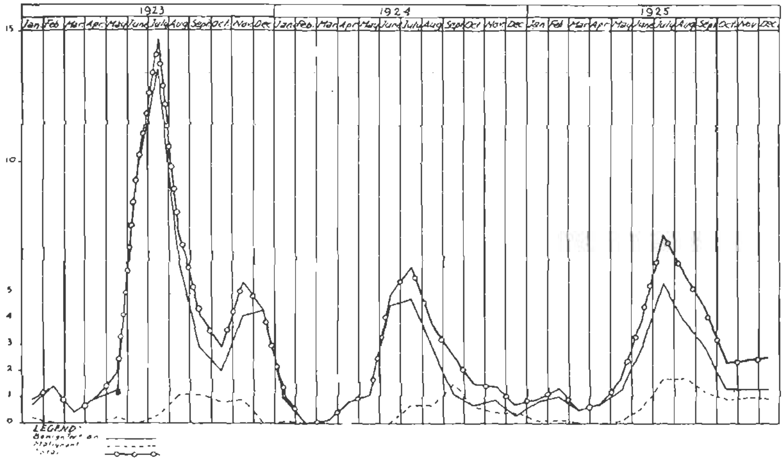
Our experience in Palestine furnishes another striking illustration of the relation of the bionomics of the anopheline vectors to the epidemicity and seasonal character of the disease. The types of the breeding-places along the coast differ materially from those in the Valley of Esdraelon and the Valley of the Jordan. In harmony with this fact the two sections of the country present two entirely different epidemic curves, as shown by a separate analysis of the data on the incidence of primary infections for the Coastal and Inland Plains, respectively. The Coastal Plain includes the districts Ekron, Petah Tikvah, Hedera, Zichron, Athlit, and Yazur (the Kishon Area), while the Inland Plains include Merhavia, Ein Harod, Yabniel, Jordan, Migdal, and Rosh Pina.

The results are shown in Charts XII–XV. It will be noted that in the coastal areas there is practically only one epidemic period, the one in June–July–August, and that the type of malaria is mainly benign tertian. There is a minor epidemic of malignant tertian malaria, but it is insignificant as compared with that of benign tertian. In the inland plains, on the other hand, the epidemics occur primarily in the fall and the prevailing type of malaria is malignant tertian. In both plains epidemics occurred at both seasons in 1923, but since then, as a result of control, the fall epidemic has disappeared along the coast while inland the summer epidemic has become negligible. It is noteworthy that in the two divisions of this small country there are two distinct epidemic pictures.

The relation of these epidemics to the prevalence of the known anopheles vectors is striking. As illustration we present two charts (Charts XVI and XVII) showing the parallelism of mosquito prevalence and associated epidemics for Hedera and Gan Shmuel in the Coastal Plain, for Dagania in the Jordan Valley, and for Rosh Pina in Upper Galilee. The relation of the epidemics to anopheles prevalence and the monthly interval (exogenous cycle and endogenous incubation period) between the maximal mosquito prevalence and the epidemic peaks are also striking.

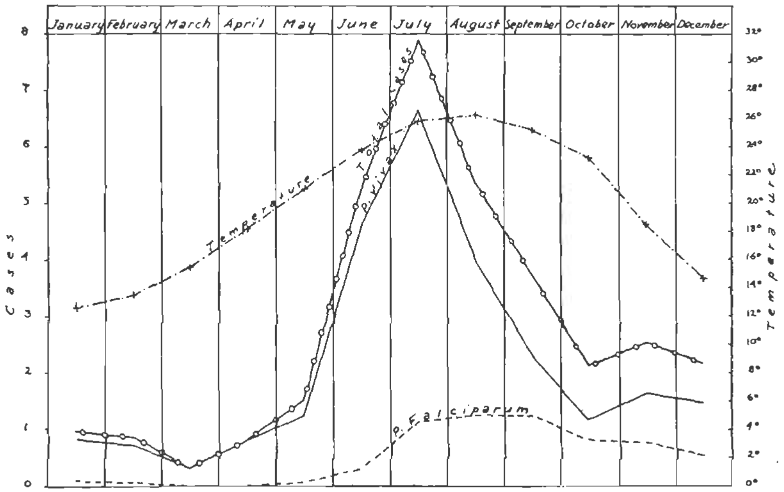
These curves also demonstrate three important sets of conditions. The Hedera curve is characteristic for the coast and the

CHART XII



SEASONAL OCCURRENCE OF *P. vivax* AND *P. falciparum* IN THE COASTAL PLAIN

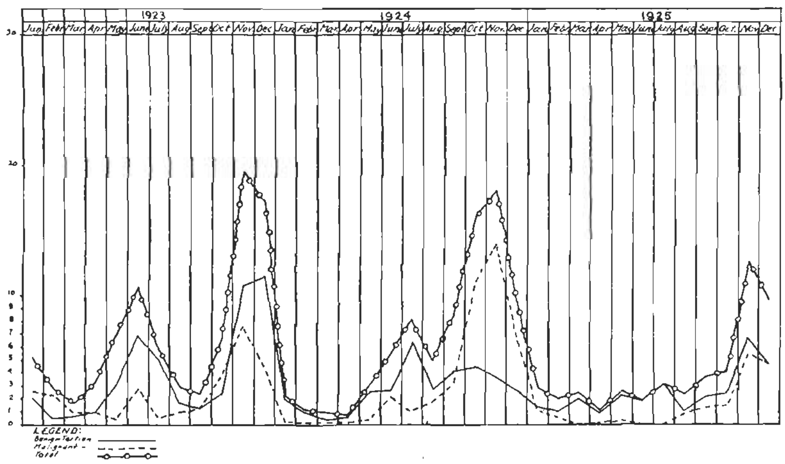
CHART XIII



AVERAGE CURVE SHOWING EPIDEMICITY AND SEASONAL OCCURRENCE OF *P. vivax* AND *P. falciparum* IN THE COASTAL PLAIN

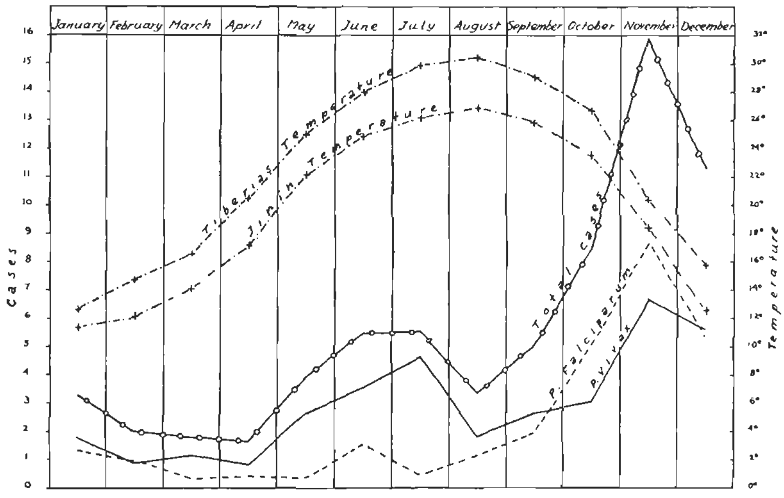
low prevalence of anopheles in the fall is associated with the absence of a second epidemic rise. In the Jordan Valley *elutus* control in the spring is easier than *sergenti* control in the fall, and consequently

CHART XIV



SEASONAL OCCURRENCE OF *P. vivax* AND *P. falciparum* IN THE INLAND PLAINS

CHART XV



AVERAGE CURVE SHOWING EPIDEMICITY AND SEASONAL OCCURRENCE OF *P. vivax* AND *P. falciparum* IN THE INLAND PLAINS

the main epidemic occurs in the fall, with only a minor rise in July. The maximal incidence of *M. sergenti* is in October, and the maximal prevalence of malaria is in November. In Rosh Pina there are practically no mosquitoes and no malaria throughout the greater part of the year. In November there is a sudden large influx of both *M. sergenti* and *A. elutus* (presumably, as was suggested in the foregoing, for hibernation), and following that there is an epidemic outbreak in December. Similar relations to that in Rosh Pina have been observed in the Metullah District in Upper Galilee and in Herzlia and Ranana along the coast.

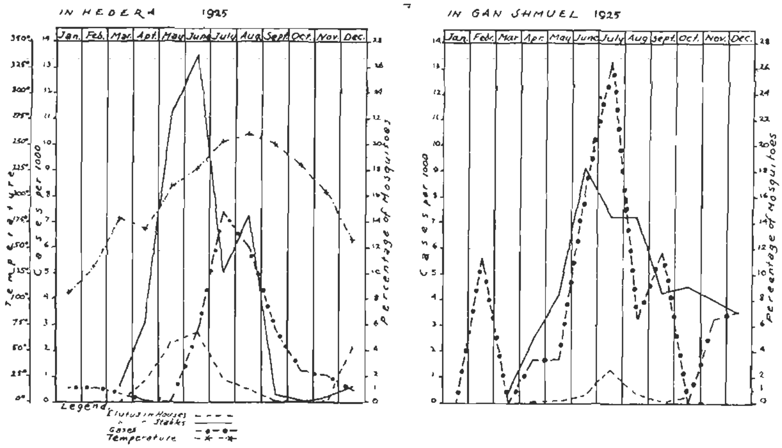
Since the anopheles vector is the determinant of seasonal epidemicity, it is essential to understand the climatological conditions affecting mosquito-breeding. Temperature, as was indicated in the foregoing, is one of the primary factors. However, in a country of seasonal rainfall the quantity and distribution of the rains during the winter play a determining rôle. Depending on the extent of suitable breeding-places, the number of mosquitoes may be so greatly reduced or increased as to produce a marked change in the epidemicity of the disease. Temperature and rainfall are, therefore, the primary climatological factors concerned in the epidemiology of malaria.

Temperature.—Perhaps of greater importance than air temperature are the temperatures of the breeding-places and of the rooms and stables where the adults take up their abode. A knowledge of the variation of the water and indoor temperatures is an important supplement to that of the outdoor temperature, because the first determines the rate of development of the immature stages while the second perhaps as much as the last affects the activity of the adult mosquitoes.

It is also important to determine the maximum and minimum temperatures. Our measurements of the morning and afternoon temperatures of various types of breeding-places have shown that there is only a general relationship between water and air temperatures, and that wide differences between morning and afternoon temperatures often occur, owing to diverse causes. Relative humidity and wind, by influencing the quantity and rate of evaporation profoundly affect the surface temperature of the water. Surface area

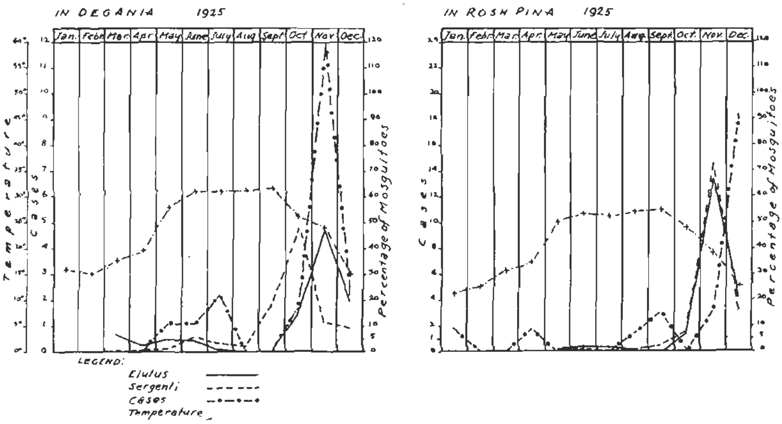
in relation to depth and degree of exposure to direct sunlight also produce wide variations and fluctuations in the range of tempera-

CHART XVI



CORRELATION OF EPIDEMICS AND PREVALENCE OF ANOPHELES IN COASTAL ZONES

CHART XVII



CORRELATION OF EPIDEMICS AND PREVALENCE OF ANOPHELES IN INLAND ZONES

ture. Moreover, spring waters often have a temperature of their own, sometimes remarkably uniform throughout the year, and quite distinct from that of pools and other stagnant bodies of water. Some temperature data of typical breeding-places are summarized in Table XLI.

Indoor temperatures in Palestine are more directly related to those outdoors than are water temperatures, because of the con-

TABLE XLI

TEMPERATURE OF BREEDING PLACES IN 1925 IN DEGREES CELCIUS

Place	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
					Stagnant Water					
Zichron....	18	18	19	20	21	22	21	19	18	16
	25	29	30	30	35	36	30	28	25	20
Haifa.....	......	......	......	......	......	......	21	18	16	14
	......	......	......	......	......	......	30	28	22	20
Balfouria..	16	17	20	23	23	25	23	22	20	15
	25	28	29	30	30	32	29	27	25	20
Yabniel....	20	25	27	28	29	33	30	25	23	21
	26	31	33	34	34	35	34	29	27	24
Migdal....	......	......	28	28	29	30	30	28	27	23
	......	......	31	31	33	34	32	32	30	24
Rosh Pina.	16	19	23	26	27	29	24	20	19	15
	25	29	29	31	33	34	31	27	23	19
Metullah..	16	18	23	26	26	26	23	22	19	14
	24	29	30	31	31	31	26	25	22	19
					Spring Water					
Zichron....	17	17	18	19	20	20	20	19	18	15
	23	25	26	27	28	28	26	25	24	17
Balfouria..	15	17	19	21	23	24	22	21	20	14
	22	23	25	26	28	25	27	25	24	18
Nuris.....	17	18	20	22	23	23	22	20	......	......
	23	24	24	25	25	25	24	23	......	......
Migdal....	......	......	27	27	28	29	29	27	26	23
	......	......	28	29	31	32	30	30	29	23
Yabniel....	18	22	24	26	27	28	27	24	21	20
	23	25	27	29	30	31	29	27	25	22
Rosh Pina.	16	18	21	25	25	27	24	20	19	15
	22	24	25	28	29	30	28	25	22	17
Metullah..	16	18	21	24	25	25	22	20	19	13
	20	24	26	27	27	28	25	23	21	17

NOTE.—The first row of figures were the readings in A.M., the second in P.M. A.M. is from 7:00 to 8:00 in the morning; P.M. from 11:00 to 1:00, midday.

ductivity of the common building material (stone) and lack of permanent heating arrangements. Here too, however, there are considerable variations depending on the type of building material, thickness of the walls, degree and character of ventilation, wind and sun exposure, etc. On the whole, the indoor temperature is more constant than the outdoor and is not subject to the same variations

during different parts of the day. This is important because the adult mosquitoes appear to select their resting places as near to the optimum as is obtainable at the particular period of the year.

The temperature effect is twofold. First, the winter temperatures, outdoor air as well as water, are so low that adult activity is slackened and larval development completely stopped. The house temperature, though usually from two to three degrees higher than that of the outside air, is also as a rule sufficiently low to inhibit the activity of the adult mosquitoes. During January and February the air temperature in the hiding-places (magazines, store-houses, cellars), even in the plains, is usually below 16° C. (as a rule from 10° to 12° C.), although occasionally warmer places are found with a temperature of 17° C. In addition to limiting the activity of the mosquitoes, the sexual development of the parasites in the mosquito may be either retarded or completely prevented, according to the temperature of the hiding-places of the adults. In our dissections we have found *elutus* with active sporozoites during the winter months, but this was obviously a case of survival; these mosquitoes were infected in the fall before they entered winter quarters. In a series of laboratory infections at temperatures below 17° C., no development of the parasite occurred.

The other important point is that the maximal summer temperature in Palestine is too high for mosquito activity. Our observations indicate that the high temperature in August has a direct effect on the adult as well as on the immature stages of *A. elutus*. The exact relation has not as yet been fully established. There are, however, definite indications that the maximal water temperatures of 34°–36° C. exert a harmful effect particularly on young larvae. During the same month the adult mosquitoes seek shelter in the coolest parts of stables and show a slackening in their general activity and particularly in their egg-laying capacity. Our observations thus far also indicate that of eggs of *A. elutus* laid in the summer a much smaller percentage hatch. This twofold effect of high temperatures explains, on the one hand, the concentration of adult *elutus* in stables during the month of August and, on the other, the sharp drop in both adults and larvae during September and the first

half of October. Only during the months of March to the middle of July, and October to the end of November, is the temperature favorable to the full activity and development of *A. elutus*. These relationships between temperature and anopheles prevalence are brought out by the curves presented in the foregoing.

Rainfall.—The relation of precipitation to the epidemiology of malaria in Palestine has been discussed at length in a previous chapter. It was shown that the quantity and distribution of rain during the winter determine largely the extent of the epidemic during the following summer and fall. The winter of 1924-25 furnished an ex-

TABLE XLII

RAINFALL FOR 1924–25 AND 1925–26

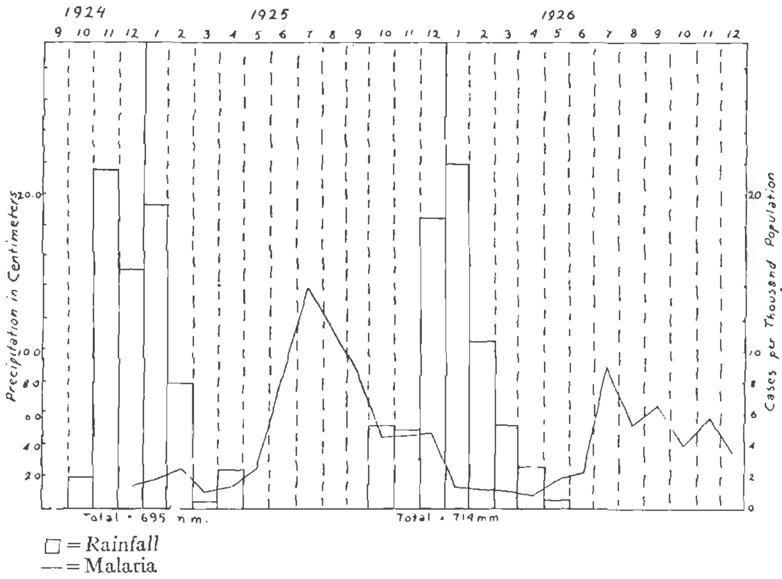
(In Millimeters)

From the Report of the Department of Agriculture

Place	Year	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
1. Haifa...	1924–25.	1	0	0	0	20.0	216.0	152.0	194.0	81.0	5.0	27.0	0.0	695.0
	1925–26.	0	0	0	0	54.5	52.9	186.3	220.8	108.0	55.2	27.7	7.1	714.5
2. Tel Aviv	1924–25.	0	0	0	0	29.0	29.0	219.0	80.0	50.0	4.0	25.0	0.0	336.0
	1925–26.	0	0	0	0	11.9	81.7	68.3	117.3	81.1	40.8	33.1	7.0	441.2
3. Tiberias.	1924–25.	0	0	0	0	0.0	26.0	120.0	62.0	33.0	4.0	40.0	0.0	285.0
	1925–26.	0	0	0	0	0.0	43.0	84.5	111.0	85.0	73.5	35.0	3.0	435.0
4. Safad...	1924–25.	0	0	0	0	0.0	158.0	105.0	157.0	45.0	3.0	51.0	0.0	519.0
	1925–26.	0	0	0	0	27.0	15.1	100.0	287.0	189.5	149.5	65.0	55.0	888.1

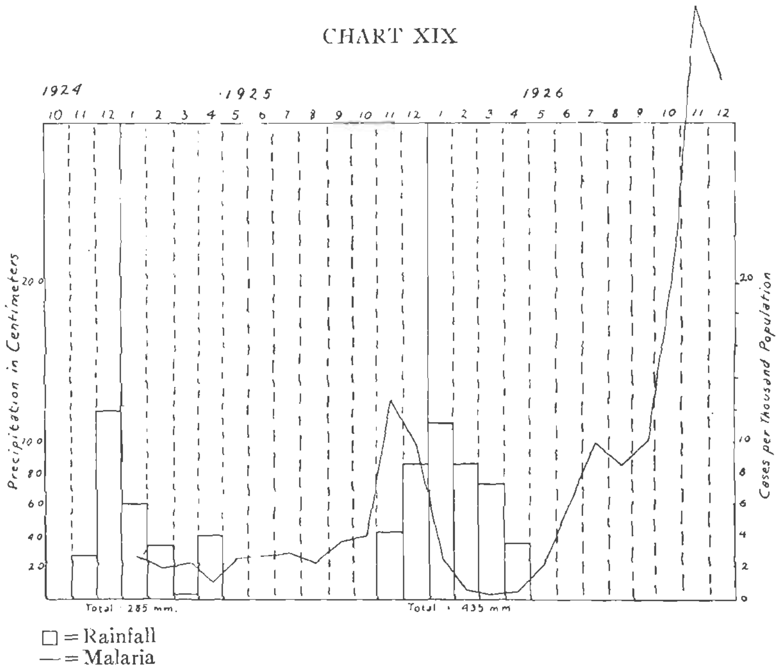
cellent opportunity to check this relationship. The rains were below normal for the year, and in addition they were concentrated in the first part of December and the month of January. During these periods great volumes of rain fell in a few days. The result was as predicted—the springs were very low in water while the coastal marshes were very extensive. As a consequence, there was a serious epidemic in Hedera along the coast, while in the Merhavia and Rub-el-Nasra region water was scarce and malaria negligible. In general, the malaria that year was relatively prevalent along the coast and uncommon inland. In 1926, the distribution along the coast was more uniform than in 1925 although the total quantity was about the same; in the Inland Plains, the distribution was more uniform and the quantity greater than in 1925. As a result, malaria along the coast was quite low while that in the Inland Plains was relatively

CHART XVIII



RELATION OF RAINFALL TO MALARIA PREVALENCE IN THE COASTAL PLAINS

CHART XIX



RELATION OF RAINFALL TO MALARIA PREVALENCE IN THE INLAND PLAINS

high. These facts are brought out in Table XLII, giving the distribution of rainfall in 1925 and 1926, and the charts, showing the relative prevalence of malaria during these two years in the Coastal and Inland Plains, respectively. The relation of quantity and distribution of rainfall to malaria epidemicity is clearly demonstrated.

Range of dispersion.--Another important variable associated with the habits of the anopheles which greatly affects the epidemiology of malaria has been entirely overlooked. Heretofore it has been assumed by most workers that the range of flight of anopheles is very limited, from 1 to 1.5 kilometers. This may be the case in some countries and under certain conditions. In Palestine and in Italy the range of flight is much greater. We have had epidemics in settlements 2.5 kilometers from the nearest swamp. Moreover, we have practically conclusive proof that by gradual dispersion anopheles have traveled from 3.5 to 5 kilometers from their source.

The long-distance dispersion seems to be associated especially with the hibernating flight. In 1923, an epidemic occurred in Rosh Pina due to *A. elutus* which had presumably traversed a plain 6 kilometers in extent. The evidence was only presumptive, but no other source was found. In 1925, outbreaks occurred in Segera from a source 4.5 kilometers and in Ranana from a source 6 kilometers away.

All of these outbreaks had the same general characteristics. They occurred in November and December, and they were caused by *A. elutus.* There were no breeding-places of *A. elutus* in a radius of 4 or more kilometers from the settlements. During the spring epidemic season, neither mosquitoes nor malaria cases appeared there. In the fall, early in November, *A. elutus* (sometime also *M. sergenti*) began to make their appearance, and these were soon followed by either sporadic cases or small epidemic outbreaks of malaria.

This phenomenon was so unusual that at first no adequate explanation could be found. A repetition of this experience, followed by a closer study of the conditions, led to a solution of the problem. Here, again, it was evident that a knowledge of the social conditions

of the country is essential in interpreting the facts. In Palestine, the agricultural population lives in compact villages or large farms. There are no scattered homesteads as there are in the United States. If a village is located near a marsh it absorbs most of the mosquitoes, but some of them find their way to the next village some distance away. The farther villages are protected by those near the marsh.

If, however, the nearest village is from 2 to 3 kilometers away, the mosquitoes fly out in all directions and many reach that village. During the active breeding-season, the majority of the mosquitoes return to the marsh again; a few of the many may find their way to other neighboring villages, as a rule not more than 1 kilometer or so away. In the fall when the hibernating flight is going on, the mosquitoes pass from one village to the next, and disperse over large areas previously free from anopheles and considered quite safe. The outbreak of malaria depends on the number of infected mosquitoes invading the village, as well as on the weather—whether winter sets in early or late.

Another important factor enters into this dispersion. Usually the Bedouins are camped on the flat lands near the marshes, and act as shock-absorbers, taking up a good part of the anopheles population. During October and November, they move from their summer to their winter quarters, that is, from the low-lying marsh lands to higher, if they are semipermanent dwellers in the region, or to the east and south if they are nomads. In either case, the mosquitoes hidden in the tents are driven to seek shelter elsewhere, and at the same time the barrier is removed and dispersion stimulated. A similar effect is produced in the Fellah villages by the removal of the kitchens from outdoors into the houses. The smoke drives the mosquitoes out of their shelter to seek more favorable quarters elsewhere.

These findings are based on actual studies of the density of the anopheles population in a widening radius from the source of breeding. The epidemic in Nahlat Jacob, the outbreak in Segera, and those in Ranana, Herzlia, Kfar Saba, and Rosh Pina were traced in this way. There is no longer any doubt that the clustered villages, the peculiarity of the local village life, together with the habits of the Bedouins, facilitate anopheles dispersion, particularly at the be-

ginning of the hibernating flight, to distances previously considered impossible. That many of these mosquitoes are infected is indicated by the dissections carried out in Rosh Pina. Of eighty *A. elutus* taken in stables and cellars during December, three were infected, two of them with sporozoites.

THE MALARIA PARASITES

There are several points in the epidemiology of malaria particularly associated with the characteristics of the malaria parasite or specific resistance of the host which are still obscure. It is our experience here as well as that of other workers elsewhere that during particular seasons certain types of malaria occur. This seasonal occurrence is quite sharply defined in Palestine. During April there is, as recorded in the preceding chapter, always a rise in benign tertian malaria, due principally to relapses. During June-July there is a B.T. epidemic. During October–November there is a malignant tertian epidemic. Why is there a quiescence in relapses during the winter and a sudden sharp rise in April? Why do B.T. malaria epidemics occur in June and M.T. epidemics in October? These are questions which are as yet unsolved.

The occurrence of relapses seem to depend on certain ill-understood phases of host resistance. We have approached this question in the laboratory from another angle. We have studied the question of host resistance to trypanosome infection in experimental animals. There it seems that host resistance depends on the reticulo-endothelial apparatus. The injection of olive oil, which blocks the macrophages, or benzol, which destroys the leucocytic cells, or massive doses of dead trypanosomes, which apparently also block the cells, breaks down this resistance, and causes relapses in previously infected animals, or a prompt invasion of the circulation in newly infected ones.

These observations offer no explanation of the spontaneous occurrence of relapses in general and their sudden excessive increase in April after three months of quiescence. One possible explanation is that the sudden access of sunshine after the winter is responsible for the outbreak of relapses. Lenz has reported the experimental production of relapses in twenty-three out of thirty-eight patients ex-

posed to sunlight. In our experimental studies of trypanosome infections in guinea-pigs, we have found that daily irradiation by exposure to sunlight or chilling by immersion in a water bath increases the susceptibility of the animals to blood invasion. It is possible, therefore, that in malarial infections the same effect is produced, and that sudden overheating or irradiation after a cold sunless winter reduces the resistance of the host so that the parasites multiply actively and invade the circulation.

Regarding the prevalence of the benign tertian type of malaria in June–July and the malignant type in the fall (October–November), we are even more in the dark. There are two hypotheses possible. One is that the external temperature affects differently the exogenous development of the two parasites, that the *P. vivax* finds optimum conditions at a temperature lower than that required by *P. falciparum*. The other is that the seasonal occurrence depends on variations in the host resistance to these two parasites at different times of the year. The former hypothesis is simpler and more readily susceptible of experimental verification. In fact, some evidence already exists that the two parasites have different temperature optima, but it is as yet meager and inconclusive.

A good review of the literature on this subject is presented by Mitzmain. Grassi was, apparently, impressed by the possibility of an epidemiologic relation between the effect of temperature on the exogenous development of the parasite and the seasonal prevalence of the different types of malaria. His experiments seemed to establish a difference in the effect of temperature on the development of *P. vivax* and *P. falciparum* in the mosquito. His results, however, were not fully confirmed by other investigators.

On the whole, the experimental data are not conclusive. There is a lack of comparable observations on the rate of development of the oöcysts of the two parasites at the different temperature ranges occurring throughout the year, as well as the time required by each parasite to reach the infective or sporozoite stage at given temperatures. In most instances, only the lowest temperature was ascertained at which oöcysts developed. Mitzmain studied the effect of normally fluctuating temperatures on sporozoite development, and concluded that oöcysts may be maintained for a long

time without developing sporozoites, and that "intermittent low temperatures, even when temperatures favorable to parasite development are present in the early stages," prevent exogenous development. No comparative studies with the two parasites were made.

King studied the effect of low temperatures on sporozoite development of *P. vivax* and *P. falciparum*. He found that the former parasites will survive two days at 30° F., four days at 31° F., from six to seven days at 45°–69° F., and in some instances seventeen days at 38°–59° F.; the parasites of *P. falciparum*, on the other hand, resisted the cold only from one to two days at 35°–57° F.

Roubaud found that in *A. maculipennis* at a temperature of 17° C. *P. vivax* developed in fifteen days, while *P. falciparum* required twenty days. Wenyon found a similar difference in *A. maculipennis* at a temperature of 18°–25° C., but found no corresponding difference in *M. superpictus*.

It is clear from this résumé of the literature that there is some difference in the effect of temperature on the exogenous development of the two parasites, but the experimental data are not sufficiently comprehensive to warrant any conclusion. This question requires more thorough investigation.

The second hypothesis is more difficult of experimental verification, since it is difficult to experiment with the human host, and even if that were possible, as in paretics, there are many variables which complicate the conditions. The fact that malignant tertian malaria is more readily cured than benign tertian in itself indicates a difference in the reaction of the host to the parasite. *In vitro* no difference is noted in the behavior of *P. vivax* and *P. falciparum* to quinine; *in vivo* such a difference does exist. This difference in itself is, however, only suggestive, and much more conclusive evidence will have to be brought forward to establish such a relationship.

It is evident how many variables enter into the epidemiology of malaria. It is only by focusing our attention on them, by keeping them constantly before our eyes, that we can hope to clear up some of the unknown elements in the epidemiology of this disease. A full understanding is possible only when all the doubtful elements entering into the problem are cleared up.

CHAPTER VII

METHODS OF CONTROL

One of the great disappointments of the World War in the field of preventive medicine was the failure to make any appreciable impression on the course of malaria. On practically all the southern fronts, Albania, Macedonia, Palestine, and Mesopotamia, the prevalence of malaria was great. Serious inroads were made in the effective strength of the various armies. No efforts were spared to control the disease, and all available means, including extensive quininization, were used. The results were, however, far from encouraging. The causes of the failure are not fully known. Nevertheless, the experience of the war has been of great value in that it has drawn attention to a number of facts and shattered a number of peace-time convictions.

The etiology and mode of transmission of malaria are well known. On the basis of this knowledge, two main lines of attack have been proposed for combatting this disease. Each of these methods aims at breaking a link in the chain of the life-cycle of the plasmodia. One method, proposed by Koch, attacks the parasite in the human host principally by means of quinine, the specific drug for this parasite. The other method is the one used by Gorgas and Ross, and consists in an attack on the insect vector, the anopheline mosquito.

Theoretically, either method applied with vigor should give successful results. Experience has not, however, fulfilled these expectations. Gorgas, Carter, and their co-workers achieved excellent results in Panama by using antimosquito methods. Bass has reported favorable results in Mississippi by mass treatment with quinine. But the practically complete failure on all war fronts to check the inroads of the disease is clear proof that practice does not coincide with theory, and that there must be certain elements in the transmission of the disease which are not clearly understood.

This is perhaps the most important lesson with regard to malaria

that the war experience has taught us. We have come to realize that malaria is eminently a local problem, and that a successful attack is possible only after a careful study of the local conditions combined with systematic experiments with the method or methods most likely to give the desired results.

In the course of our work during the last five years, various methods of control have been tested. Antimosquito measures as well as quininization have been experimented with under different conditions. The results will be presented in the subsequent chapters. Before discussing the results, however, it is desirable to describe the general procedure followed in the organization of the control areas and the antilarval and antimosquito measures employed in our work.

ORGANIZATION OF A MALARIA CONTROL AREA

1. *Survey.*—Any attempt at malaria control should be preceded by a thorough malaria survey. The general procedure of such a survey is essentially the same as that of any other epidemic disease, except that one needs bear in mind the fact that malaria is an insect-borne disease. The survey should include, among other things, a thorough study of the kinds of anopheles breeding within the area, their habits, seasonal occurrence, etc. In Palestine it is best to begin the survey in March, preferably in the latter part of the month. In our work, control in each new district was preceded by a survey covering the following main points, usually in the order given.

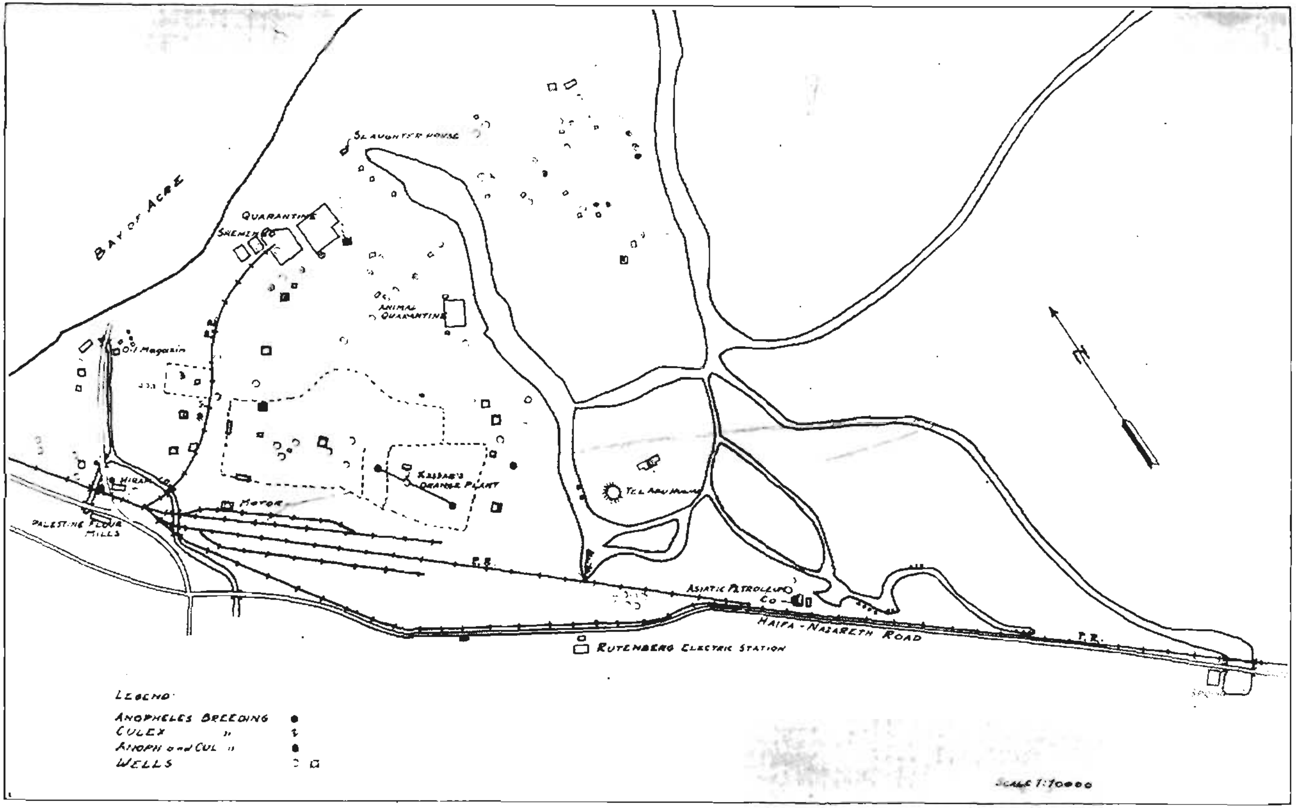
a) Climatological and social survey.—The first information required before the actual malaria survey can be started is of a general character, principally on two subjects. It is most important to have reliable data of the climatology and topography of the district; the distribution and volume of rainfall; the temperature; the character of the inhabitants, and their social and economic conditions. The volume and distribution of the rainfall and the character and formation of the soil have a fundamental relation to the formation of swamps; the temperature determines the extent of breeding and the seasonal distribution of mosquitoes, while the type of inhabitants determines the method of measuring the endemicity and epidemicity of malaria.

The importance of the social and economic factors in the epidemiology of malaria, and in the proper interpretation of the results of the blood and spleen rates, or epidemiological data, has been indicated above. For one not familiar with conditions in Palestine, for example, it would be difficult to understand why the spleen rates in two adjacent villages influenced by the same marsh should be three times as high in one as in the other (Merhavia and Solim). When, however, he is told that one is a progressive Jewish village with a resident physician and the other a backward Arab village receiving practically no medical care, the results are intelligible. Similarly, without knowing the movements of the Bedouin tribes and the high incidence of carriers among them, it is difficult to explain the occurrence of an outbreak of malaria in the Transylvanian group at a time when and place where anopheles were extremely rare. However, knowing that many Bedouins were camping in the vicinity and that the settlers were all recent immigrants, the occurrence of the cases is understandable. It is clear, therefore, that information of a general character is an essential prelude to an intelligent inquiry into the specific problem—malaria.

b) Anopheles survey.—A general sketch map of the district was obtained or made on the spot. On this map were indicated all the villages and houses, the wells, cisterns, and reservoirs; the springs, streams, wadis, and pools. This map contained all the potential breeding-places in so far as known. On the basis of this map a thorough examination was made of the various places indicated, as well as of the district as a whole, in order to check the information and add any additional breeding-points, actual or potential, not included. The survey covered an area of a radius of 3 kilometers from the main population center. On this map or copies of it, the extent and kind of breeding found at different periods was recorded, as is usually done on spot maps. In this way a comprehensive knowledge of the breeding conditions in the area to be controlled was obtained. A typical survey map is attached.

At the same time a careful search was made in all the houses, stables, storehouses, and cellars for adult mosquitoes which had hidden themselves during the winter. This gave an idea of the number and kinds of anopheles and their relative density in different

MAP X



Mosquito Survey of Kishon Area

villages in the area. During the year, weekly searches were made in selected houses in order to get a comprehensive index of the types of anopheles occurring during the different seasons of the year, and their relative density.

In this way a complete picture was obtained of the types of anopheles, their breeding-places and their relative prevalence during the different periods of the year.

c) *Carrier survey.*—While the antimalaria inspector checked up the sketch map and searched for mosquitoes, a physician was detailed to investigate the prevalence of the disease. The physician's records, if available, were examined and a blood and spleen examination of the inhabitants made. In the course of this examination, inquiries were made concerning the disease and, specifically, the malaria history of the inhabitants. The three classes of data (physician's records, personal history, and blood and spleen indices) furnished a comprehensive picture of the malaria prevalence in the area. In some places record cards were made for each inhabitant so that the full information obtained was available for reference. This obviously could not be done in every place.

With this information available, the plans for systematic control were worked out. First of all, particularly in places where the medical service was unsatisfactory, systematic treatment of the carriers discovered during the examination was instituted under the charge of the local inspector. At the same time attempts were made to bring the breeding-places, in so far as possible, under control.

During the period of control, the study of the habits of the local anopheles and other environmental factors was continued. The intensity of breeding was recorded each week, and larvae were sent regularly to the laboratory for examination. Adult mosquitoes caught in the selected houses were dissected regularly in order to ascertain the index and distribution of infected mosquitoes.

2. *Organization of the control area.*—After the survey was completed, the real task, the organization of effective control, began. Most often this involved a preliminary period of education. It was necessary to educate and win the support of the local physician or nurse, chief of the village, or the administrative committee. As a rule, there was no trained personnel, and people had to be trained

to do the work. Finally, it was important to enlighten the population and win their support.

The physician very often had to be educated in two things: first of all, that he exercise special care that the treatment be carried out effectively; second, he had to be convinced of the importance of keeping careful records of the clinical and laboratory diagnosis and of prompt reporting. Morbidity data proved of prime importance in the study of the epidemiology and progress of malaria, and such data could only be obtained with the aid and co-operation of the local physician.

The actual success of any control measure depends on the quality, training, and dependability of the local inspector. The selection and training of this class of personnel is, therefore, of the utmost *importance in malaria control. The man should be sufficiently intelligent* to grasp the elements of the theoretical basis of the work and become interested in the work as such, and to understand the responsibility resting on him. He should also be ready to do the work, and not merely stand by and order someone else to do it. These are considered essential qualities, and only such men were selected who possessed both of them.

The education of the inhabitants was the third, and by no means the least important, element which conditioned the success of the work. Without active co-operation on the part of the people, the work would have been only partially successful. It was possible to obtain their active co-operation only after they understood fully the significance and value of the work.

The fourth important step in the effective organization of a control area was the constant supervision. The work of the inspector, as well as that of the physician, had to be checked at frequent intervals, particularly during the early stages. This also had an educational value because it kept the question alive, offered opportunity for advice and discussion, and continued the training. It also often enabled one to correct mistakes before the consequences could become serious, and to detect any delinquency in the work. After a man was trained and tried, he could be left a good deal on his own responsibility, but supervision and direction were always necessary.

The physician's records and findings also required checking, be-

cause physicians as a rule were lax in systematic recording of the diagnosis. A useful procedure was to make the physician check the work of the inspector and, vice versa, have the inspector obtain personal histories of each patient whose name was submitted to him by the physician. The inspector would receive the names of the patients weekly or semiweekly, visit all patients at their homes or in the hospital, check up their past malaria history, and send the returns to the central office. In this way reliable morbidity data were ob tained and possible epidemics averted as a result of the prompt reporting.

The procedure outlined in the foregoing proved its usefulness in the course of our work. It proved the essential need of investigation before control. It acquainted us with the various elements entering into the epidemiology of the disease. Finally, it provided the raw data for a synthesis of the epidemiology of malaria in Palestine. With such knowledge, control proceeded on a sure footing and the possibility of successful results was much greater.

MOSQUITO CONTROL BY LARVA DESTRUCTION

The essential thing is to have a thorough knowledge of the type of breeding-places and the habits of the local mosquitoes, and to apply the appropriate method to the particular local set of conditions. Just as it is difficult to generalize about methods of control for a given country, so it is dangerous to assume that any one method of mosquito control is suitable under all conditions. First, it is essential to ascertain whether mosquito control is possible and then whether it is to be directed against the larvae or against the adults. Then it is necessary to suit the method to the given local conditions.

The most effective results can be expected by a concentrated attack on the breeding-place of the anopheles. Wherever possible it is more economical and equally effective to direct attention to the known vectors and to ignore the other species of anopheles. Control of species rather than general anopheles control has been our aim. This saves a great deal of time and needless expenditure of funds.

The methods of mosquito control which have proved of value in our experience may be divided into three categories: (1) mechanical, (2) chemical, and (3) biological.

Mechanical methods.—Wherever possible the mechanical method is the method of choice. Under this head we include the method of eliminating breeding by removing the conditions which favor it. In some places we resorted to drying; in others, where that was difficult, the vegetation was cleared in order to create conditions unfavorable to anopheline development. Breeding-places of *M. sergenti* and *M. superpictus* caused by springs can often be easily dealt with: (1) by

FIG. 15.—Control gate, Jordan River mill run

deflecting the flow in a different direction from the natural course every five or six days, or (2) by damming the stream, storing the water behind the dam for two or more days, and then releasing it. These simple measures have been used by us extensively with excellent results.

1. In seepage areas the water can be collected in open or subsoil collecting channels and directed to a convenient point, where it is alternately sent in open channels running in different directions. Irrigation canals can be treated the same way; our practice has been to dry them completely once a week for from thirty-six to forty-eight hours by sending the water into the natural stream bed.

These methods allow drying of all water channels. Thorough drying is essential; otherwise the larvae, particularly older ones, breeding in these streams and channels may remain alive for a considerable time in the moist earth, and resume their activity as soon as the channels are refilled with water.

FIG. 16.—Sluice gate for control of irrigation canals

Where funds are available, springs may be collected and the water disposed of in subsoil tile drains with excellent results. The accompanying illustrations show the various methods described in the foregoing. Detailed schemes will be described in the chapter on drainage.

2. Another method which has proved useful is the impounding of streams by construction of a dam at a suitable point. This permits the drying of the stream bed. The water in the reservoir behind the dam may be used for irrigation or other purposes. When the reservoir is full, a sluice gate in the dam is opened and the

water released. In this way both the stream bed and the reservoir are dried at intervals sufficiently short to prevent the emergence of imagos.

Stagnant pools are of two kinds. Some are temporary in character and dry up from one to four months after the rains have stopped. Others persist all year. When these pools have clean banks and are free from floating vegetation, *A. elutus* rarely breeds there. When overgrown with water plankton—potamogeton, ranunculi, chara, and algae—they constitute favorite breeding-places of *A. elutus*. During May and June, such pools may be literally black with *A. elutus* larvae.

FIG. 17.—Damming a small stream with earth-filled sacs.

An effective method then is to clean these pools thoroughly about April, at the beginning of the breeding-season, and then keep them clean. If the latter proves too expensive, one of the chemical methods, preferably Paris green, should be used at required intervals after the first cleaning.

The cost of these various methods of control varies. Control of smaller springs is usually cheap. Often the antimalaria inspector can do the work himself or with the aid of a laborer for a few days each month. The cost of damming up small streams may vary from L.P.[1] 10 to L.P. 75, according to the size of the dam, and the volume of the water to be stored.

Cleaning of pools and larger perennial streams, such as the Jor-

[1] L.P. = Pounds Palestinian = Pound Sterling.

dan, is more expensive. The initial work usually requires clearing of the banks of foliage as well as aquatic vegetation, and may run up to L.P. 20 a kilometer. Subsequent maintenance for the entire year is usually not more than L.P. 10 a kilometer. The average cost a kilometer a year is about L.P. 20.

The mechanical method properly employed gives absolute results. Consequently, even when a trifle more expensive, it is the method of choice.

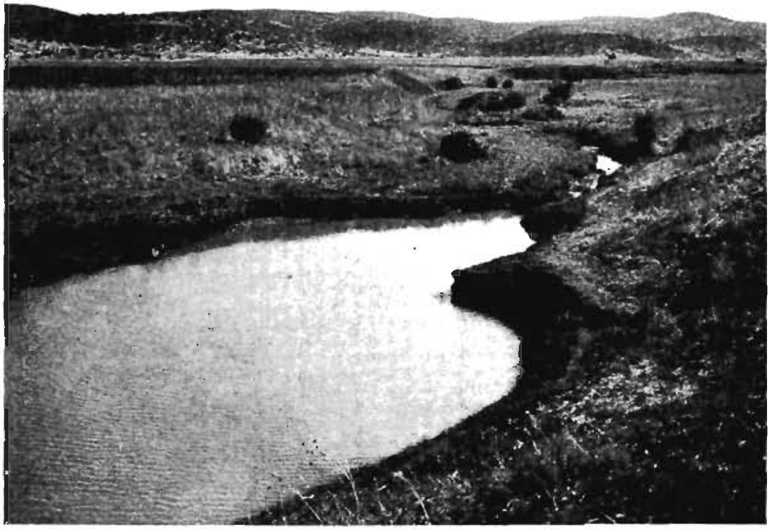


FIG. 18.—Bed of the Kishon after removal of vegetation

Chemical methods.—After much experimentation, we found that three chemical larvacides give satisfactory results under suitable conditions. These are: (1) paraffine—crude oil mixture; (2) Paris green; and (3) cresol.

1. *Petrolization and petrolizing mixtures.*—One of the important and useful methods of antilarval control is the oiling of the surface of breeding-places. A good oiling mixture should possess the following properties: good spreading and penetrating power, a uniform film, good tensile strength, and, if possible, a readily visible color. Pure kerosene lacks all of these properties; even when 25 cc. are

used for each square meter of surface area. In rare places where there is little vegetation, little wind, and no dust on the surface of the water, ordinary kerosene may be satisfactory.

In Palestine, most of the breeding-places are covered with vegetation, winds are prevalent and usually strong, and there are often during the active breeding-season greater or lesser films of dust on the surface of the water. Kerosene alone is, therefore, quite unsuitable for oiling. Crude oil, the heaviest residue in the distillation of paraffine oils, added in the proportion of one part to four parts kerosene produces greater spreading power, greater tenacity, and gives a more uniform film. The film does not, however, have sufficient penetrative power to spread out among the vegetation. Efforts were therefore made to improve the oiling mixture. As a result of a large series of tests with various paraffin mixtures, vegetable oils, and oleic acid, we found that castor oil, first used by Leak, is best suited for increasing the spreading and penetrating power of kerosene and kerosene mixtures. The addition of 0.1 per cent by volume of castor oil is sufficient to increase the kerosene film by ten and the film given by the crude oil mixture by four. It also greatly increases the penetrative power. Other oils (olive, sesame, cottonseed) were unsatisfactory. Amydal oil gave the same results as castor oil. Most powerful in its effect is oleic acid, but the film becomes too thin to be effective. This acid has an explosive effect on the oiling mixture, due probably to a lowering of the surface tension by the unsaturated fatty acid.

Our experiments were first made in the laboratory and then tested in the field under controlled conditions. Briefly summarized, we found that a kerosene-crude oil mixture of 9:1 or 4:1 gave a uniform film about five times as large as that of an equal amount of kerosene alone, and of much greater tensile strength. Fifteen cubic centimeters of the mixture per square meter of surface were ample. The addition of 0.1 per cent castor oil to this mixture increased the rapidity of spreading and the extent of area covered. Ten cubic centimeters of this mixture per square meter gave a better film than 15 cc. of the foregoing, with better penetrative power. Two-hundredths per cent oleic acid in the kerosene-crude oil mixture causes an extremely rapid spreading of the film over an area

five times that of the castor oil mixture. This film is, however, extremely unstable.

The larvacidal power of the mixtures depends on two factors: (1) the completeness with which the film covers the surface, and (2) the length of time it remains intact. The larvae take advantage of a break in the film to escape the poisonous effect of the paraffin oil. In addition to the spreading power, etc., one must also be sure that the film is sufficiently durable to have adequate larvacidal effect. In general, our laboratory experiments have shown that the same amounts of different mixtures under identical conditions produce the following results:

Kerosene alone requires from twenty to twenty-five minutes to kill all the larvae.

Kerosene plus crude oil requires from fifteen to twenty minutes.

Kerosene–crude oil–castor oil requires ten minutes.

Kerosene–castor oil requires twenty minutes.

The majority of the larvae were usually killed during the first few minutes, and only two or three out of ten would remain alive twenty minutes or longer, according to the quantities and mixtures used. These mixtures are much more effective against anopheles than against culex larvae.

The field larvacidal tests corresponded with the laboratory experiments. In the practical field work from 10 to 15 cc. of the paraffin–crude oil mixture containing 0.1 cc. of castor oil gave the same results as twice that amount of paraffin and crude oil spread over the same area.

Summarizing our experiments with various oil mixtures, it appears (1) that castor and amydal oil and oleic acid greatly influence the spreading and penetrative power of paraffin and paraffin mixtures. Oleic acid is particularly powerful in this respect. (2) The castor oil gives a uniform film of greater degree of stability than does the oleic acid. Also, the castor oil is cheaper and more readily obtainable everywhere. All of these considerations decided in favor of the adoption of the former.

The oiling mixture now used consists of kerosene (paraffin), 4 parts; crude heavy motor oil, 1 part, and castor oil, 0.1 per cent, by volume to the mixture. Pure kerosene seems to have greater toxic

effect than the impure products (mazute) on the market. For crude oil, any heavy machine oil can be used. The foregoing mixture satisfies all the requirements enumerated. The film produced has good spreading and penetrating power, uniformity, and resistance, and the crude oil imparts a color that can be seen long after the kerosene has completely evaporated.

2. *Paris green.*—This larvacide is being used by us most widely. Roubaud was the first who tried to poison larvae with a toxic powder. In 1920 he showed that larvae could be killed by dusting trioxymethylene powder on the surface of breeding-places. The surface tension of the water keeps the fine dust on the surface for several hours. The larvae pick up these particles of dust just as they do particles of food on the surface of water, and are literally poisoned.

Barber looked for a cheaper substance than trioxymethylene, and found that Paris green or Schweinfurt green (copper acetoarsenite) used so much as an insecticide is an efficient larvacide. It is particularly effective in places overgrown with vegetation, the very places where paraffin mixtures are of little if any value.

In Palestine, Paris green has yielded excellent results. It is in every way preferable to paraffin. Its effectiveness may be judged from the figures in Table XLIII and Table XLIV. We followed Barber's original method and found it entirely satisfactory. One part Paris green is mixed with 100 parts of fine sifted road dust or ashes, and 1 kilo of the mixture (10 grams Paris green) is scattered over 100 square meters of marsh.

This larvacide has many advantages over oiling. It is effective among aquatic vegetation where oiling is often useless; where there is an abundance of water plankton, it remains on top of the vegetation and is ingested by larvae two or three days after it is applied. It is less cumbersome to handle than paraffin mixtures, and is five times as cheap. It is not dangerous for cattle. Analyses made in the laboratory showed that the powder contained only 2.2 per cent soluble arsenic, while the water from treated pools taken shortly after treatment contained only from 2.5 to 0.4 parts arsenic per million.

Paris green has certain drawbacks, but these are not very serious. (1) It does not affect pupa, and during the active breeding-season has to be applied every week instead of every ten days, as in

the case of oiling mixtures. (2) It is not effective against culices, and consequently is useless in any general antimosquito campaign.

TABLE XLIII

LARVACIDAL ACTION OF PARIS GREEN*

No.	Description	No. of Dip-pings	No. and Stage of Larvae				Results† No. of Larvae				Per Cent Reduction
			1st	2d	3d	4th	1st	2d	3d	4th	
1.....	Pool covered with algae	30	22	23	13	33	0	0	0	0	100
2.....	Pool with scattered patches of algae	54	68	41	19	1	14‡	0	0	0	89
3.....	Pool with scattered patches of algae	40	16	20	16	1	4	0	0	0	92
4.....	Pool thickly overgrown....	30	48	12	15	15	3	0	0	0	91
5.....	Pool covered with potamogeton	32	19	11	6	2	1	0	0	0	97

* The number of dippings made before and after the application of Paris green was always the same.

† Analysis of Paris green showed that it contained 2.2 per cent of soluble arsenic. Samples of water taken two or three days after treatment and analyzed showed 2.5, 0.4, and 0.5 parts per million of arsenic.

‡ It should be noted that the first stage larvae are the ones most apt to escape the effect of the arsenic; probably they are too small to ingest the particles of arsenic powder.

TABLE XLIV

LARVACIDAL ACTION OF PARIS GREEN

Place	No. of Dip-pings	Before Treatment Larvae Stages			No. of Dip-pings	After Treatment Larvae Stages		
		1st	2d	3d		1st	2d	3d
Ein Ganim, overgrown pools..........	32	......	38	......	50	7	0	0
	30	8	5	3	30	0	0	0
	50	16	7	4	30	3	0	0
	40	17	6	9	100	4	0	0
	30	12	7	3	30	3	1	0
	70	19	10	5	70	4	2	0
Ramath Gan, overgrown stream.........	62	29	13	9	80	7	0	0
	40	3	0	1	55	6	0	0
	70	15	31	16	65	2	0	0
	50	4	3	13	68	2	0	0

NOTE.—Practically the only survivals are the smallest first stage larvae; apparently they are too small to ingest the particles of Paris green.

(3) It can only be used when and where a good cheap diluent (dust or ashes) is available.

In Palestine these drawbacks are not of serious moment. In the rural areas we are chiefly interested in anopheles. When culex breeding in watering holes or artificial containers becomes too bothersome,

the paraffin mixture is used. The diluent, road dust, is plentiful during the greater part of the breeding-season. Difficulty may be experienced only in April and October—at the end and beginning of the rainy season. But this difficulty is easily overcome by storing up enough dust from one season to the other.

Composition of Paris green.—The substance known as Paris green in the United States is copper aceto-arsenite ($3CuHAsO_3 - Cu(C_2H_3O_2)_2$), a double salt of copper arsenite and copper acetate. In Europe it is known as Schweinfurt green. In the pure state it con-

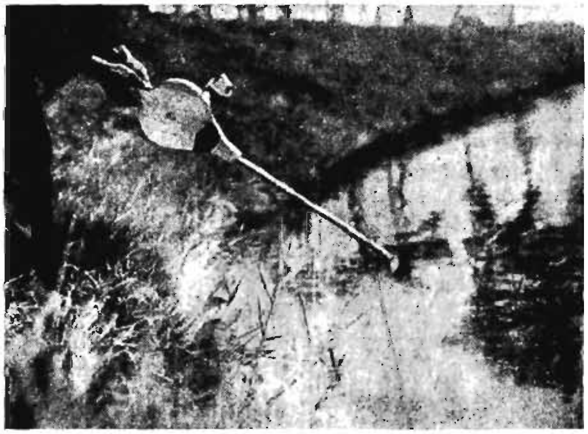


FIG. 19.—Bellows for spraying Paris green. (From Hackett)

tains 58.62 per cent arsenious anhydride, and the United States law requires a minimum of 50 per cent arsenious oxide. It is a green powder practically insoluble in water. The commercial products contain varying quantities of extraneous substances, and are often badly adulterated. A good quality will average more than 50 per cent of arsenious oxide. Every new lot should be tested for its arsenic content as well as its larvacidal power.

Diluents.—Road dust is the cheapest and best diluent for Paris green. Only fine dry dust is suitable. It is necessary, therefore, to screen the dust and store it in a dry place. If sufficient amounts of dust cannot be obtained, wood ashes and mill bran are good substitutes. Sand is not satisfactory because it sinks readily and carries the Paris green with it.

Proper mixing is essential for success with Paris green. Failures are often due to improper mixing. Mixing should always be done mechanically in a tight box. It is always best to mix small quantities at a time.

Distribution.—This is best done by hand, throwing the mixture in the air in such a way that the wind will carry the dust cloud over the face of the water. The hand blower or bellows (see Fig. 19) employed by farmers to dust vines, recommended by Hackett, is useful in treating streams. It saves time and material, and enables the worker to direct the dust between vegetation and bushes along the irregular banks. For pools and stagnant marshes, our inspectors prefer the hand method of distribution.

Quantity.—The tendency among inspectors is to use too much. This should be avoided as wasteful and unnecessary. The object is larval destruction, and a 1 per cent mixture properly applied gives the desired results. A stronger mixture than 1 per cent may be used in certain cases, but this is rarely required.

Precautions.—The persons who distribute Paris green suffer no ill-effects if they take a few simple precautions. It is important to keep to windward of the dust cloud, to keep the clothing well buttoned, and to wash the hands properly immediately after work. We have had a few instances of irritation in the scrotal region or throat. But this happened only when the men were careless. After the first year there were no recurrences of these complaints.

3. Cresol is a useful larvacide, but is limited in its applicability. Its effect on anopheles and culex larvae differs from that of paraffin. A paraffin mixture which kills culex larvae in fifteen minutes will destroy anopheles larvae in one or two hours. Cresol, on the other hand, in dilute solution of 1:5,000 or higher kills anopheles larvae in one-third to one-fourth of the time required to kill culex larvae (see Table XLV). The two larvacides may, therefore, complement one another. Under certain conditions cresol added to the kerosene mixture (1 per cent cresol) gives excellent results.

In practice cresol is effective only in concentrations of 1:10,000. Its use in large bodies of water or deep pools is, therefore, impracticable. Its usefulness is limited to shallow pools and particularly to so-called gravel swamps, where there is a small volume of water

flowing slowly under gravel beds. On windy days when quick action is required, 1 per cent cresol added to the paraffin mixture gives excellent results. Cresol has the added advantage that it delays the

TABLE XLV

Type Experiment Illustrating the Effect of Cresol and Paraffin on Mosquito Larvae

Time of Exposure	Cresol Solution				Paraffin Mixture		Paraffin Mixture with 1% Cresol	
	1:5,000		1:10,000					
	10 Larvae		10 Larvae		10 Larvae		10 Larvae	
	C. pipiens	A. elutus	C. pipiens	A. elutus	A. elutus	C. pipiens	A. elutus	C. pipiens
10 minutes	....	....	....	....	....	....	all dead	....
15 minutes	3 dead	6 dead	0 dead	5 dead	3 dead	10 dead	....	all dead
30 minutes	5 dead	9 dead	0 dead	6 dead	6 dead	....	....	....
1 hour	9 dead	10 dead	2 dead	8 dead	8 dead	....	....	....
2 hours	10 dead	....	5 dead	10 dead	8 dead	....	....	....
3 hours	....	....	8 dead	....	10 dead	....	....	....
6 hours	....	....	9 dead	....	....	....	....	....
12 hours	....	....	....	....	....	....	....	....

reappearance of new larvae for several days. In places treated with paraffin or Paris green, new larvae (first stage) may be noted the first or second day after treatment. In places where cresol is used, new larvae do not appear until four or five days later.

TABLE XLVI

Relative Cost of Different Larvacides
(Per 100 Square Meters of Marsh)

	Per Application	Per Month
Paraffin mixture	P.T. 1.2, or 6.0 cents	P.T. 3.6, or 18 cents
Paris green and dust	P.T. 0.3, or 1.5 cents	P.T. 1.2, or 6 cents
Cresol (shallow pools depth 0.1 meter)	P.T. 6.0, or 30.0 cents	P.T. 12.0, or 60 cents

The relative cost of the three larvacides, discussed in the foregoing, calculated per hundred square meters of swamp is approximately that given in Table XLVI.

It will be seen that cresol is about three and one-half times as costly as kerosene, which is three times as expensive as Paris green.

The last is, therefore, from every standpoint the substance of choice. Under special conditions when one or the other substance cannot be used, cresol, preferably in combination with the paraffin mixtures, is a dependable and useful larvacide.

4. $CuSo_4$ was used at first in irrigation reservoirs, for the destruction of algae and, indirectly, of mosquito larvae. In a concentration of 1:500,000 or 1:1,000,000, it gives very satisfactory results. Lately, however, we have abandoned this in favor of fish.

Biological methods.--Under biological methods are included in the first instance larvae-eating fish. We have succeeded in acclimating *Gambusia* brought from the United States, and have also experimented with the native *Cyprinodons* and *Tylapia.*

In evaluating the usefulness of fish in mosquito control, it is important to define clearly the conditions under which observations are made. Fish have definite limitations as antilarval agents, and, unless these limitations are borne in mind, their real usefulness may be overlooked. In confined reservoirs, fairly clean pools, or canals, one may obtain excellent results, while under overgrown conditions fish and larvae will exist side by side quite happily. There is always a balance between fish, other food, and larvae. The results depend on the relative concentration of fish and of other food besides larvae.

The native *Cyprinodons* are not particularly effective as destroyers of larvae. They are not top feeders, and rarely hunt their food among surface plankton. When confined in small clean pools or aquariums, they will keep them free from culices or anopheles. In pools covered with algae or surface vegetation, they are practically useless.

With *Gambusia* we have had more satisfactory experience. It took about two years to discover the optimal conditions under which they will thrive. Now we have fairly large numbers in the open drainage canals and pools near Hedera and Zichron, and they thrive even in the colder climate of Jerusalem. Their usefulness as larvae-destroyers under local conditions where vegetation is abundant and the microfauna rich enough to supply their needs without great trouble, is limited. In moderately clean canals, on the other hand, or in pools having a limited food supply, they yield excellent results.

The other native fish, *Tylapia,* has proved very useful in the

control of mosquito-breeding in the orange-grove reservoirs. These reservoirs constituted a serious and difficult problem. In the orange-growing district, each grove has one large cement reservoir, into which the water is pumped, and several smaller ones for the distribution of the water in different directions. These reservoirs rapidly become overgrown with a mat of *Spirogyra* and offer good breeding conditions for *A. elutus*. Cleaning the reservoir of vegetation is a costly process. Treatment with copper sulphate had to be repeated once a month, and then the dead algae had to be removed to prevent their clogging the distributing pipe.

In observing the various small native fish, it was noted that the *Tylapia* are omniverous feeders. Under confined conditions in the laboratory, they eat algae, vegetable matter, such as leaves and young shoots, larvae, and young *Cyprinodons* or *Gambusia* with equal voraciousness. This fish breeds in most of the streams of the country, grows to the size of the perch, and is a good eating fish. The first experiments were not reassuring, but as soon as the numbers grew, the results were excellent. It is, apparently, a question of balance between the number of fish and the rate of growth of the algae. When there are forty or fifty fish per tank, it remains permanently clean. At times it was found that the grove-owners even added food (bread).

This fish has three advantages. It eats vegetation and is thus of economic benefit to the owner, because he is spared the periodic cleaning of the tank. It does not readily fall prey to other fish or snakes. Finally, the fish being edible, the owner removes the larger ones, and watches the progress and well-being of the younger ones. In this way, we have been entirely relieved of the problem existing in the orange groves, except to see that tanks which are dried during the winter are restocked when irrigation begins. This is true only of a small percentage of reservoirs.

This experience is a good illustration of the importance of studying each problem as it exists locally. It also demonstrates that one need not limit one's self to any one variety of fish. Sometimes a local fish may give better results than an imported one, which has proved useful elsewhere. The very term biological implies that there must be an adaptation to the particular environment.

Chara is common in Palestine, but we have failed to note any antagonistic action on larvae. On the contrary, in ponds where patches of chara exist, one is more likely to find larvae of *A. elutus* among them than in the open water.

DESTRUCTION OF ADULT MOSQUITOES

Destruction of adult mosquitoes may serve as an aid to larval control. Under certain conditions in which larval control is not possible it is useful as an added measure of control. It is particularly useful in the case of hibernating mosquitoes, which often travel long distances from their breeding-places, and may even cause epidemic outbreaks.

There are various methods for catching and killing adult mosquitoes. The method employed must vary with the conditions and particularly with the season of the year. It should be borne in mind that during the active season, we are primarily concerned with the anopheles in houses and only secondarily with those in stables. During the winter, however, anopheles are rarely found in houses (this is true of Palestine, although it does not, apparently, apply to other countries, particularly colder countries where the houses are well heated and suitable for anopheles), but hide principally in warm storehouses, ill-ventilated stables, and cellars.

During the active period, advantage may be taken of the habit of anopheles to leave the house just before sunset. Our observations have shown that there is an attempt on the part of anopheles, as well as other insects, to leave houses about half an hour before sunset. This phenomenon has been used by us for their effective destruction. All windows and doors of the room are darkened except one. The various places where mosquitoes are likely to hide, the underside of beds, tables, sofas, and clothes, are disturbed so as to drive them out. After a time many of the anopheles, excepting perhaps some of those which had a feed that day, come to the single lighted window and are destroyed there. The whole operation takes little time, and the members of the family can be drawn in to assist in the sport.

In Bedouin tents the only effective way is to catch the mosquitoes in cyanide, chloroform, or spirit tubes, or spray them with formaline. In the hands of a skilled inspector the alcohol tube is

quite a simple and effective way of catching mosquitoes when they are not wanted for preservation or dissection. A little alcohol is placed in an ordinary test-tube, and the tube closed with the thumb and shaken each time before placing over the mosquito in order to moisten its lips. As soon as the tube is placed over the mosquito, she begins to fly, her wings are moistened by the alcohol, and she sticks to the tube. In quick succession tens of mosquitoes can be caught in this way in a single tube. This method in the hand of an experienced inspector is to be preferred to spraying, and in tents where there are large numbers, it assures a higher percentage of killed mosquitoes.

Spraying is not, in our experience, a very effective way of destroying anopheles on the wing and we rarely use it. The mosquito must be moistened by the spraying fluid; otherwise she is not seriously hurt. Often one sees stunned mosquitoes recover and fly away. The best spraying fluid is Giemsa's. In our work we used a mixture of two parts formaline and one part liquid soap. The spray should be fine and so directed as to hit the resting anopheles; otherwise the results are not very satisfactory.

For destruction of mosquitoes in stables, particularly hibernating anopheles, the following procedure is useful. All parts of the stable, except the door, are darkened and a sheet is hung over the door; a heavy smoke is then generated with moistened straw or straw mixed with a little manure. The smoke drives the mosquitoes from their hiding-places and they come half-dazed to the door as the only source of light and means of escape. There they can easily be caught and destroyed. The only drawback to this most effective method is the hardship experienced by the inspector who suffers from the smoke. Some relief may be obtained by crouching near the floor. It is a useful method, particularly where chemical fumigation is not possible for one reason or another. It is also far less costly, since no materials are required, and it takes far less time.

In mud houses and during the winter, when complete destruction of hibernating mosquitoes is desired, chemical fumigation has proved effective. The Arab houses have no windows, and the hiding-places in the woven twig ceilings and cornices are so numerous that hand-catching is time-consuming and at best only partially successful. Similarly, in storehouses and cellars, it is not always

easy to find the hiding anopheles. Under these conditions chemical fumigation is resorted to. The advantage of chemical fumigation is that incidentally it destroys vermin, which often infest these houses.

The places are prepared in the usual way for fumigation: all crevices are closed with glue paper; all doors and windows are closed, and only one free access is left. As soon as the fumigant is started, this opening is shut tightly and the process allowed to continue for several hours.

Both sulphur and cyanide are effective fumigants. For sulphur fumigation, about 4 kilograms of sulphur are required for 1,000 cubic meters of space. The powder is put in a flat container and placed on a petrol tin. A little alcohol is poured over the sulphur to facilitate the starting. As soon as everything is ready, the alcohol is lighted and the door closed tightly. The fumes should be allowed to remain several hours. To obtain an idea of the number of anopheles, a sheet may be placed on the floor so that the dead mosquitoes may be readily seen.

Cyanide fumigation is practiced only on rare occasions where complete closing of the cracks is not possible. The great toxicity of this compound renders its use undesirable except under special conditions. The house is prepared in the same way as for sulphur fumigation. For every thousand cubic meters of space, the following substances are required: 1 kilo NaCN (sodium cyanide); 800 cc. H_2SO_4 (sulphuric acid), and 3,000 cc. water.

First the cyanide is weighed out in a piece of paper. The acid poured carefully into the water (and not the water into the acid), the cyanide thrown in, and the room left instantly. The door is closed tightly, and the gas allowed to act about two hours. After that the doors and windows are opened, and the room is thoroughly aerated before anyone is allowed to enter. Usually, at least from six to eight hours are required for aeration.

Since both these gases are apt to be absorbed by foodstuffs and sulphur is particularly deleterious to various articles of furniture and clothing, all these things should be removed from the house or storeroom before fumigation is started, and should not be returned until the gases have completely disappeared.

As already stated, these methods are only used in exceptional cases. They are too cumbersome, expensive, and time-consuming.

CHAPTER VIII

RESULTS OF MALARIA CONTROL WORK

In the foregoing chapters an attempt had been made to present a rounded picture of the malaria situation in Palestine as it existed before or at the time control was undertaken. A description was given of the actual and potential breeding-places, the mosquito vectors and their habits, and the conditions favoring the breeding and extension of the mosquito host. Emphasis was laid on the heterogeneity of the population, the relative incidence of parasite carriers, and the endemicity and epidemicity of the disease among the different sections of the population. With these data as a background, it is now possible to discuss in some detail the results of the control measures employed.

In evaluating the results of his efforts, the epidemiologist is always confronted by the question, To what extent have the measures employed been responsible for the effect? Malaria, like many of our social and community diseases, may gradually disappear with the improvement of economic conditions, the more intensive settlement of the country, and the intellectual development of its inhabitants. Progress of civilization is accompanied by regression of malaria. Moreover, malaria, like other endemic-epidemic diseases, has waves of high and low epidemicity.

Before analyzing the results of conscious control efforts, it is necessary to review in brief the evidence showing that spontaneous regression did not play an important part in the reduction of malaria in rural Palestine. It has been pointed out in the preceding chapters that malaria was highly prevalent both before and during the World War, and that after the war there was a severe epidemic throughout the country in 1920 and 1921. It was also shown that during the years 1921–26, inclusive, the carrier incidence, as measured by the parasite and spleen rates, has not appreciably decreased in villages located in non-control zones. There has, likewise, been no diminution in the epidemicity of the disease in localities where mosquito

control has not been possible, Hedera, Benjamina, Gan Shmuel, and Jissr. Even more conclusive evidence is obtained from the experience in widely separated settlements where control was intermittent, Migdal, Ramath Gan, and Shchunat Borochov. This negative evidence concerning the absence of spontaneous regression strengthens the positive results, to be discussed later, obtained in areas where conscious and effective control has been carried out.

TABLE XLVII

AVERAGE MONTHLY INCIDENCE OF MALARIA 1922–25 IN PLACES WHERE MOSQUITO CONTROL FAILED OR WAS NOT ATTEMPTED

(Per Thousand Population)

Place	Year	Population	Relapses	New Cases	Total‡
Hedera*	1922	698	...	...	47†
	1923	650	41	16	57
	1924	764	27	9	36
	1925	906	20	19	39
Gan Shmuel	1923	39	106	13	119
	1924	41	87	31	118
	1925	47	126	28	164
Benjamina*	1923	116	25	8	33
	1924	169	21	7	28
	1925	234	21	10	31
Jissr§	1925	50	...	...	104†

* Control not successful.

† No classification of cases was made.

‡ The annual fluctuation noted is due to local factors, such as greater or lesser breeding, larger number susceptible population, etc.

§ Control not attempted. On the average each man had two attacks per month; not a single individual escaped infection during the first year.

If we consider the problem from another angle, it is also apparent that no spontaneous regression is conceivable in Palestine. The epidemicity of an insect-borne disease is affected by three factors: (1) the distribution of the parasite; (2) the concentration of the susceptible population, and (3) the prevalence of the insect host. All these conditions are amply fulfilled in Palestine. The problem is further aggravated by the two countermovements of population groups discussed in the foregoing. On the one hand there is the steady influx of immigrants from non-endemic countries into this highly endemic center, and on the other there is the constant extension and distribution of parasites by the annual migration of Bedouins from winter to summer quarters and vice versa. Between

October, 1922, and October, 1926, the Jewish population has increased from 82,000 to 156,000, an average influx of 20,000 susceptible people a year, aside from the natural increase in the indigenous population. At the same time, the heavily infected Bedouin roams

TABLE XLVIII

INCIDENCE OF MALARIA IN PLACES WHERE COMPLETE, PARTIAL, OR NO MOSQUITO CONTROL WAS CARRIED OUT IN SUCCESSIVE YEARS

INCIDENCE OF MALARIA IN RAMATH GAN AND SHCHUNAT BOROCHOW, 1923–25

Month	Population	Total Cases	Incidence Per 1,000	Population	Total Cases	Incidence Per 1,000	Population	Total Cases	Incidence Per 1,000
	1923 Complete Mosquito Control			1924 No Mosquito Control			1925 Partial, Irregular Mosquito Control*		
May	411	3	7	695	20	29	630	17	27
June	411	0	0	695	24	35	710	4	6
July	595	5	8	695	34	49	726	9	12
Aug.	595	6	10	695	30	43	710	8	11
Sept.	595	0	0	695	33	47	740	19	26
Oct.	595	0	0	630	3	5	730	11	15
Nov.	595	0	0	630	2	3	730	4	5
Dec.	595	0	0	630	0	0	730	4	5
Average per month	549	1.75	*3*	671	18.3	*27*	713	9.5	*13*

INCIDENCE OF MALARIA IN MIGDAL FARM FOR THE YEARS 1921, 1924, AND 1925

Month	Population	Total Cases	Incidence Per 1,000	Population	Total Cases	Incidence Per 1,000	Population	Total Cases	Incidence Per 1,000
	1921 Thorough Mosquito Control; Experimental Demonstration			1924 No Mosquito Control			1925 Partial Mosquito Control		
Apr.	287	12	42	49	0	0	50	1	20
May	314	2	6	49	3	60	120	0	0
June	346	2	6	49	8	163	120	3	25
July	359	7	19	71	5	70	70	4	57
Aug.	313	3	10	50	0	0	130	0	0
Sept.	305	3	10	50	0	0	140	1	7
Oct.	270	3	11	70	13	185	160	6	37
Nov.	262	11	42	78	12	153	165	28	164
Dec.	233	2	9	81	3	37	164	6	36
Average per month	336	5.6	*17*	68	5.5	*81*	140	6.5	*44*

* In 1926 there was complete control and the average incidence was 1.9 per 1000.

over the country as freely and distributes the parasites as actively as heretofore. It is obvious that under these circumstances spontaneous regression is hardly to be expected in the short interval since 1921. On the contrary, the steady influx of a susceptible population into a highly endemic focus would be expected to maintain the epidemicity at a high level.

It seems, therefore, correct to assume that any marked degree of reduction of malaria which has been obtained in the control areas in Palestine is due to conscious effort, whatever its nature, and that any absence of reduction is due to the failure of such efforts. On the basis of the correctness of this assumption, we shall proceed to discuss the results of the various methods of control employed in each area and the per capita cost of these measures.

MALARIA CONTROL WITH ANTILARVAL MEASURES

Malaria control in Palestine by antilarval and antimosquito measures has now been continuous for periods of four to six years, and, consequently, it is possible to evaluate its merits and efficacy. In most of the areas under control, there has been a steady downward tendency. The first three demonstrations conducted in 1921 in highly malarious areas resulted in a malaria reduction during the first year ranging from 82 to 91 per cent at an annual per capita cost of $1.40 to $2.36. The successful results achieved in these places led to an extension of the work to various parts of the country. At the time of writing, malaria control is being carried on in eleven districts, covering a total area of 800 square kilometers and comprising a population of 40,000. The efficiency of the control varies somewhat from year to year, but fluctuations of this sort are to be expected. Perhaps the most important cause of this variability is the difference in the effectiveness of the work of the local inspectors. There are, however, other reasons, among them still unknown elements in the epidemiology of malaria. As the specific local conditions within each control area are more thoroughly studied, control becomes easier and more effective, and the results more uniform.

For purposes of completeness it will be best to describe the progress of the work in each demonstration area separately, outlining

in each case the nature of the problem, the results, and cost. This procedure may involve a certain repetition of details, but it will, on the other hand, tend to emphasize also the variability of the problem in different localities.

The problem.—The nature and extent of the malaria problem in rural Palestine has been described in some detail in previous chapters. In some respects, the malaria problem in Palestine is relatively easy. The average amount of rainfall is usually about from 20 to 25 inches, and it is mostly concentrated during the winter period, i.e., December to March, inclusive. There are only a few large marshy areas of the kind seen in Louisiana in the United States of America or on the Italian coast.

In other respects, however, the problem in Palestine is much more difficult than one would expect from the relatively low and seasonal rainfall. The climate is subtropical, and this implies a long period of breeding. Here breeding of the anopheles vectors begins about the middle of March, and by the end of April it is quite active, while in Italy and in the United States active breeding does not occur until June. Similarly, the breeding-season in Palestine extends to the middle or end of November, whereas in Italy and in the United States it is at an end early in October. The result is that in Palestine we have a long breeding-season and two distinct malaria periods, June–August and October–December, while in the other countries mentioned there is really only one malaria season, July–September. The long dry season also introduces the problem of irrigation, which in many places offers serious difficulties. Finally, it is now clear that we have in Palestine at least three malaria vectors, *A. elutus*, *M. sergenti*, and *M. superpictus*. These may not all be of the same degree of importance, but about the same percentage of infection has been found in all of them and, consequently, all of them are to be considered serious vectors of the disease. This fact means that the small trickling brooklets and overgrown irrigation canals, where *M. sergenti* and *M. superpictus* breed in great abundance during September and October, are of as much significance as sources of malaria as are the extensive, stagnant marshes breeding *A. elutus*.

In brief, then, the malaria problem in Palestine is in some respects easier than that in other countries, but in many other respects

much more difficult. If Palestine is less well watered, it has a longer breeding-season and more vectors than either Italy or the United States. These facts must be borne in mind, if the results obtained in Palestine are to serve as a criterion for similar work to be attempted elsewhere. We are firmly of the opinion that these results can be duplicated in other places having similar conditions, provided the local problem is carefully studied and analogous antimosquito methods employed. In fact, Hackett has achieved equally good results in his demonstration areas in Italy.

Methods.--A thorough preliminary study of the local problem is a measure of first importance in the control of malaria. Such variables as the distribution of the rainfall, the rotation of irrigation, the character of the soil irrigated, the distribution of subsoil waters, and the types and habits of the local anopheles, all have their definite effect on the appearance and disappearnace of breeding-areas. Overlooking any one of them may have a serious effect on the results.

In our experience species control, that is, control directed against those species of anopheles proved to be vectors of plasmodia, is quite effective, and saves a great deal of effort and expense. This requires, first, a knowledge of the vectors and, second, the ability to differentiate the larvae of the different species. Sometimes a non-vector may under peculiar circumstances become a vector, but this is unusual, and a prior knowledge of local conditions would soon lead to the discovery of such unexpected occurrences.

The methods of antilarval control should be adjusted to meet local conditions. The various antilarval measures employed in Palestine have been described in the preceding chapter. The most generally applicable of these measures at present are the mechanical and the larvacide, Paris green. In our experience no other larvacide is so useful and gives such good results. The only important thing to recall is that the diluent (road dust, ashes, flour-mill dust) should be as fine as possible and the mixture uniform, and that the spraying should not be done during a strong wind. With these simple precautions carefully observed, the results approximate 100 per cent.

The *zone* of antilarval operations is of the greatest importance in effective control work. Our experience has shown conclusively

that the range of flight of anopheles is from 2.5 to 3 kilometers. The range of dispersion may, as described in the foregoing, be even greater. Consequently, one of the prerequisites for successful results with antilarval measures is to ascertain the effective range of dispersion of the local vectors during the active breeding-season and to extend the zone of antilarval operations to the required limits. The invasion at the end of the season can be counteracted by systematic destruction of adult mosquitoes.

In Palestine the aim has been more or less complete anopheles control. A hundred per cent control is neither necessary nor always feasible. It is not possible at present to fix an anopheline index below which malaria will generally disappear. The "safe" anopheles index depends on local conditions: the incidence of carriers, the number of susceptible individuals, the proportion between stables and dwellings, and their relative attractiveness for the anopheles. Since these variables are as yet difficult to evaluate, the most desirable procedure for the present is to aim, at the commencement of the work, at least, at maximum anopheles elimination within the zone of flight, which is itself dependent to some extent on local conditions, such as the distribution or clustering of houses in relation to the breeding-area.

Quinine as a prophylactic measure was not used anywhere, except for experimental purposes or where it was required for reasons of expedience to win over the local physician or the people. Even in those places, it was abandoned once the work was well under way.

EKRON DISTRICT

The Ekron District is an area in the foothills of Judea, comprising 267 square miles and 18 villages. The area centers around Wadi Surar, one of the main wadis in Judea. Some of the villages are affected by tributaries and their springs, others by eroded pools in Wadi Surar itself, and still others by both. At the commencement of the work, the number of villages included in the area was 9, with a total population of 2,210; with the improvement of conditions, the district was slowly extended so that the number of villages has been increased to 18, with a total population of 6,219.

Practically all species of anopheles are found in this area. In the

tributaries of Wadi Surar we find *M. superpictus* and *M. sergenti;* in the erosion holes in the wadi, *A. elutus* and *A. algeriensis;* near the village of Ekron, we also found a number of saline pools breeding *M. multicolor.* Anopheles-breeding was prolific in the entire area and malaria correspondingly high.

The swamps in this region have been described under Wadi Surar. Control was of a twofold character. A few of the seepage areas—Ein Koreh near Rishon Le Zion, Melat Swamp near Ekron, and Wadi Hulda—were drained. At Ein Koreh the seepage from the sand dunes was collected in subsoil drains and the water brought to a sump where it was pumped for irrigation. At Melat the seepage was collected in subsoil pipes and carried to the wadi, where the

TABLE XLIX

AVERAGE MONTHLY MORBIDITY AND COST OF CONTROL IN EKRON DISTRICT*

	1922	1923	1924	1925	1926
Average monthly incidence per thousand population..	42.0	5	1	0.7	0.06
Per capita cost of all operations in P.T..............	5.9	....	6	6.6	3.9

* In 1923, there were eleven villages, with a population of 4,720; in 1925, there were eighteen villages, with a population of 6,219.

water was impounded by means of a concrete dam and used for watering the cattle; at regular intervals, the water was released and the wadi bed dried. At Hulda the seepage was brought in subsoil pipes to the wadi and the wadi bed regulated. The pools in the Wadi Surar were cleaned and controlled with Paris green. The elimination of the few seepage areas reduced the difficulty of control and made this area practically malaria-free with a reasonable amount of supervision.

We have a twofold check on the efficacy of the control measures: (1) the morbidity in the Jewish population, and (2) the spleen rates in the Arab population. The malaria incidence in the Jewish population as a whole has decreased from an annual rate of 504 per thousand in 1922, the year before control was started, to 60 per thousand in 1923, 8.4 per thousand in 1925, and 0.7 per thousand in 1926. The per capita cost of the control operations was piasters[1] 5.9 in 1923, P.T. 6.0 in 1924, P.T. 6.6 in 1925, and P.T. 3.9 in 1926.

[1] One piaster = 5 cents.

The average monthly morbidity and cost of control are summarized in Table XLIX.

A further idea of the degree of control in this area may be obtained from the figures in Table L showing the change in the blood and spleen rates and in the malaria incidence in some of the individual villages in this district.

A corresponding reduction is noted in the blood and spleen indices in the Arab village of Naaneh, located in this area. The blood and spleen rates among the children for the years 1923–25 were as follows: 1923, the parasite rate was 30.2 per cent, the spleen rate,

TABLE L

BLOOD AND SPLEEN INDICES AND MALARIA INCIDENCE IN SOME VILLAGES OF EKRON AREA

Village	1922			1923			1924		
	Index		Monthly Malaria Incidence Per Thousand	Index		Monthly Malaria Incidence Per Thousand	Index		Monthly Malaria Incidence Per Thousand
	Spleen	Blood		Spleen	Blood		Spleen	Blood	
Gedera..........	37	5.8	67	18.8	0	17	.....	.....	0
Ekron..........	.....	15.0	140	.....	.....	11	.....	.....	1
Nahlat Yehuda...	.....	.....	75	.....	.....	4	.....	.....	0
Hulda..........	.....	.....	68	.....	.....	34	.....	.....	0

94.2 per cent; in 1924, the parasite rate was 5.5 per cent, the spleen rate, 74 per cent; and in 1925, the parasite rate was 2 per cent, and the spleen rate, 12 per cent.

It is of special interest to note the conditions in the villages Seged, Sorek, and Rafat, also located along Wadi Surar, but not included in the control zone until 1925. These villages are located along the upper part of Wadi Surar and had suffered severely from malaria until the control work was extended. The spleen index in these villages, taken March 1925, was: Sorek, 60 per cent; Seged, 73 per cent, and Rafat, 83 per cent. In 1925, twenty-two new settlers established themselves at Nahr Sorek, on Wadi Surar, a short distance from Seget, and not a single case of malaria developed during the entire year. No quinine was used, but mosquito control was complete.

PETAH TIKVAH DISTRICT

Petah Tikvah Area consists of a group of settlements clustering about the Auja and its tributaries (see map, chapter iii). The principal malaria vector in this region is *A. elutus*, breeding in the erosion holes in the wadis and in the orange-grove reservoirs. Next in importance is *M. superpictus*, breeding in the seepage areas in Wadi Musrara. The methods of control consisted entirely of chemical control plus regulation of some of the wadi beds— Abulejja, Ishkar, and Adas.

Control work was started in 1922 and has continued ever since. At first the area consisted of 3 Jewish and 2 Arab villages, with a population of 3,771. Gradually the control zone was extended, and

TABLE LI

Average Monthly Morbidity and Cost of Control in Petah Tikvah District*

	1921	1922	1923	1924	1925	1926
Average monthly incidence per thousand population..........	153	50	14.0	1.0	3.0	2.7
Per capita cost of all operations in P.T........................	....	....	8.1	4.4	3.1	4.8

* In 1923, there were five villages, with a population of 3,771; in 1925, there were seventeen villages, with a population of 9,256.

now it consists of 17 villages, with a total population of 9,266. The results of the control work are seen once more in the reduction of the malaria morbidity in the Jewish, and the parasite and spleen indices in the Arab, villages.

The malaria incidence in this area in 1921 in so far as it was possible to estimate it was excessively high; there were also many cases of blackwater fever. At present two of the villages more recently included still have a moderate incidence of malaria, but the general incidence for the area as a whole has been reduced to a negligible figure. There is no reason why with continued supervision the malaria incidence in this area, although it is unusually well watered, should not remain at the present low rate of infection.

The trend of malaria in this district is summarized in Table LI. In individual places the results are even more striking. Ein Ganim, for example, which has had a bad blackwater fever experience, has

been absolutely free from malaria since 1924. The same is true of Petah Tikvah and Mahneh Yehuda. In the other places occasional sporadic infections still occur, but the relative number is insignificant. Except for the northern group of villages in this area, which are visited by hibernating *elutus* from Birket Ramadan, a coastal swamp at present impossible to control, the malaria in this district is well under control.

The trend of the blood and spleen rate in the village Fejaz corroborates the morbidity data. In 1923, the spleen rate was 100 per cent among adults and 96.4 per cent among children under thirteen years of age. In 1924 (March), the rate among the children fell to 77 per cent. In February, 1926, the spleen rate among children was only 15.1 per cent. Since there has been no repeated systematic treatment of carriers in this village, this marked reduction in the spleen index can be attributed only to efficient mosquito control, and consequent absence of reinfections.

The districts Hedera and Zichron will be considered under another head. Antilarval control was not successful in either of these districts and, consequently, other methods of malaria control have been tried. The problems presented by these districts as well as the attempts at control and the results will be discussed in the next chapter.

ATHLIT

The settlement and village of Athlit present the same picture as do some of the villages in the other districts discussed. The history of Athlit is of special interest, because it was here that the first attempt at malaria control was made in 1911. The prevailing anopheles were *A. elutus* and *M. multicolor.* The place was ravaged by malaria, and when our control work was started in 1922 the entire population was badly infected. In 1921, the spleen rate was 78.5 per cent, a rate rarely found in the Jewish population. In June, 1922, a concessionary company began to establish a salt plant with evaporating basins. In July, an epidemic broke out, and out of 80 people 39 developed malaria. In August, there were 43 additional cases among 160 people. Under the influence of large daily doses of quinine, the number of cases slowly decreased. The infection rate apparently remained high, because at the beginning of the winter when quinine

was stopped and the men examined, the parasite rate was 26.8 per cent.

Since that time anopheles-breeding has been brought under control, malaria morbidity has steadily declined and has now practically disappeared. The decline in the malaria rate shown by Table LII is a direct result of the elimination of a large breeding-area and the subsequent control of the breeding in the Wadi Dustroh and adjacent seepage areas.

The first operation involved the elimination of a coastal marsh 180 hectares in extent. The cost, chargeable to antimalarial operations, cannot, however, be estimated, since most of the work was

TABLE LII

Monthly Average Incidence—Athlit
(Per Thousand Population)

Year	Cases
1922	203
1923	112
1924	32
1925	1
1926	5

required by the industry. The large marshy areas were converted into the evaporating and crystallizing salt pans.

The remaining breeding-areas, which require constant attention, are a perennial stream (Wadis Dustroh) with seepage areas along the sides. The cost of the care and maintenance of this wadi is P.T. 10 per capita for a population of about 300. This entire cost is being defrayed by the Palestine Salt Company.

YAZUR

The experience in this district is of special interest. Control in this area was not started until 1925, that is, long after control had been effected in other areas. A systematic study of the conditions in this area in 1924 gave us a picture of the situation prior to the control, while the active settlement of the area by several hundred new immigrants furnished an ideal test of the effectiveness of the control operations. This district may, therefore, serve as an illustration of what can be accomplished by antilarval measures thoroughly applied.

The whole area and the various breeding-places (springs, wadis, river, and marshes) are shown in the map of Kishon Valley in chapter iii. The control zone extended from Beled esh Sheikh to the west, where there were more than one hundred open shallow agricultural wells to be controlled, at first to Ein Itshak, and later to Tel es Shemam to the east. The northern limit was the line Harbaj-Jedda, and the southern the springs and pools just south of the Kishon at the foothills of the Carmel range. No control had previously been attempted in this area. It consequently furnished a virgin field for an experimental demonstration.

The principal breeding occurred in the bed of the Kishon River, which bisects the area, in Wadi Malik, and in the swamps at Harbaj and Hartieh. The Kishon, like many of the coastal streams, presents a peculiar set of conditions. It is a large stream bed with deeply eroded banks, flowing full in the winter during the rains. With the end of the rains in April, the volume of water decreases steadily until the end of June when the flow ceases altogether, and numerous large erosion pools remain until the next rains. These pools are found along the entire length of the Kishon, and offer excellent breeding conditions for *A. elutus*, the principal vector in this area. Wadi Malik is a smaller edition of the Kishon, but otherwise identical in character.

The conditions in this region vary from year to year according to the volume and distribution of the rains. In 1926, for example, because of the heavier rains, there was more water in both the tributary wadis and the Kishon, and irrigation started later. Consequently, the part of the Kishon which dried early in May in 1925 did not dry until early in June in 1926. The delay in drying meant more extensive breeding and required more intensive control.

The Harbaj and Hartieh swamps were caused by seepage and by springs which had no proper beds. The water from the seepage and springs flooded areas of 400 and 1,000 dunams, respectively, and thus created ideal breeding-places for *A. elutus*.

That the area was a bad endemic center of malaria was indicated by the examination of native villages in March, 1924 and 1925, and by the malaria incidence in a small new settlement (Achwa) established against our advice early in 1924. Since control was started

in 1925, there can be no question of a sudden "spontaneous" regression or a postepidemic effort.

It was under these conditions that there came into this area an industrial community with more than 200 workmen, and four new agricultural settlements with about 500 recent immigrants. An epidemic was imminent and, as events showed later, it would undoubtedly have occurred if measures had not been taken in time to prevent it.

TABLE LIII

MALARIA PREVALENCE IN KISHON AREA PRIOR TO CONTROL

a) BLOOD AND SPLEEN INDICES IN THE NATIVE VILLAGES ABOUT THE KISHON

Village	Blood Index				Spleen Index		
	Year	No. Exam.	No. Pos.	Per Cent	No. Exam.	No. Pos.	Per Cent
Tel Shamam.....	1925	89	15	16.3	....	....	....
Sheikh Abreik...	1925	12	3	25.0	10	6	60.0
Harbaj } Hartieh }........	1925	18	3	16.6	24	16	66.7
Yazur..........	1924	52	5	9.6	49	31	63.3

b) MALARIA INCIDENCE (PER CENT) IN ACHWA, A SETTLEMENT ESTABLISHED EARLY IN 1924

Population	Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
33.............	1924	....	....	....	0.0	0.0	9.4	34.4	28.1	39.5	34.2	50.5	68.4

In anticipation of this new settlement, control operations were started in March, 1925. The control measures consisted in clearing the banks and regulating the bed of the Kishon; in opening proper channels for the springs, and in carrying on intensive larval control with Paris green. The area was one of the most difficult ones in Palestine outside the zone of the Huleh Marsh and some of the extensive coastal marshes. There were 14 kilometers of river and wadi bed to be brought under control, as well as 5 kilometers of canals at Harbaj and Hartieh, about 100 shallow agricultural wells and many small, scattered springs and pools in the smaller wadis. Breeding was entirely under control by May 1, about two weeks after the arrival of the first group of new settlers.

The experience here is a repetition of previous experience else-

where. But this repetition is important for two reasons. First, it furnishes confirmatory evidence on the possibility of control by anti-mosquito measures. Second, conditions had been studied for a full year before the control work began, and there could, therefore, be no question as to the relation of the control effort and the results. The continued high spleen rate in the Arab population, the severe epidemic in the new settlement, Achwa, in 1924, and the epidemic, to be described later, which started in one of the new settlements in 1925, indicate clearly that the control work was being carried out in a highly endemic focus where the introduction of a large sus-

TABLE LIV

Primary Infections in the Villages along the Kishon During 1925

(Percentage Incidence)

Village	Pop.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Monthly Average
Yazur (cement factory)...	195	0.8	0	0	0	0	0.0	1.3	1.2	0.5	0.6	0	1.2	0.4
Achwa*.....	50	....	....	....	....	0	10.0	3.1	2.4	2.2	4.2	0	1.4	2.3
Nahlat Jacob..	274	....	....	....	0	0	7.4	2.9	4.0	0.3	1.2	0	0.0	2.2
Avodath Israel	118	....	....	....	....	....	0.0	1.2	0.0	0.0	0.0	0	0.0	0.2
Zichron Abraham......	36	....	....	....	....	....	....	....	....	0.0	0.0	0	0.0	0.0

* These data should be compared with those for 1924 given above.

ceptible alien population would have resulted in a serious epidemic had not adequate measures been taken to prevent it.

The results as indicated by bare incidence figures are shown in Table LIV. It will be noted (1) that there were practically no cases in one of the settlements which was started at the beginning of the epidemic season (June 24) only 1 kilometer from Harbaj and 0.5 kilometer from the Kishon; (2) that only a few sporadic cases occurred among the workmen in the cement factory; and (3) that there was a steady improvement in the conditions at Achwa, despite the addition of 15 new settlers and the presence of many chronic cases of malaria.

In 1926, the breeding conditions were worse than in 1925. The rainfall in 1926 was heavier than in 1925; there was more water in the wadis, and the pools and streams dried up later. There was also

at the same time a shifting of the sites of the settlements. Nahlat Jacob was moved to a point near the Harbaj swamp, and three new settlements were established.

The malaria condition, however, was better than the previous year. In all of the settlements, except Avodath Israel, located on the

TABLE LV

PRIMARY INFECTIONS IN THE VILLAGES ALONG THE KISHON IN 1926
(Percentage Incidence)

Village	Pop.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Monthly Average
Yazur (cement factory)...	280	0	0.0	0	0	0.0	0.0	0.3	0.6	0.9	0.0	0.0	0.0	0.3
Achwa.......	109	3	0.0	0	0	0.0	0.0	5.8	0.0	0.0	0.0	0.8	0.0	0.7
Hartieh......	125	0	0.0	0	0	0.0	2.3	5.5	0.0	0.0	0.0	0.0	0.9	0.6
Harbaj......	130	0	1.5	0	0	0.6	0.5	0.0	0.0	1.0	0.0	0.0	0.0	0.3
Avodath Israel	118	0	0.0	0	0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.6

eastern extremity of the area, the incidence of primary infection was lower than in 1925. The results are shown in Table LV.

Another indication of the trend of malaria in this area is the change in the blood and spleen indices in the village Yazur, shown in LVI.

TABLE LVI

BLOOD AND SPLEEN INDICES IN YAZUR BEFORE AND AFTER CONTROL

Year	Blood Index			Spleen Index		
	No. Exam.	No. Pos.	Per Cent Pos.	No. Exam.	No. Pos.	Per Cent Pos.
1924......	52	5	9.6	49	31	63.3
1925......	20	0	0.0	20	8	40.0
1926......	10	0	0.0	18	1	5.6

COST

The cost of cleaning and regulating the channels, chemical control, and supervision during the first year was L.E. 545.117. At this cost a population of 1,700, about 700 Jews and 1,000 Arabs, was afforded protection. The total per capita cost was, therefore, P.T. 32.6. This is the per capita cost for all charges except administration, and, though high in comparison with that in other districts, it is not excessive for the first year of control in a highly malarious

rural district, where the population is small and the villages scattered over a large area. The cost of the second year's (1926) control was only P.T. 18.2 per capita, L.E. 420 for a population of 2,300. Moreover, the improved conditions of this area will result in a more intensive settlement, and such increase in settlement will naturally bring about a still further decrease in the per capita cost. Previously, there were 5 villages in this area with about 1,000 inhabitants, many of them sick and nonproductive. At present not only is the number of villages increased but it is also expected that the population will continue to increase by the addition of new settlers as the land is brought under more intensive cultivation.

MERHAVIA AND EIN HAROD

These two districts are located in the Valley of Esdraelon. Both areas were intensely malarious. The sources of infection in both areas were the numerous springs issuing from the foothills on either side of the valley and spreading aimlessly over the heavy clay soil. The extensive marshes caused by these springs rendered the entire district practically barren of population. Around what is now Nahalal there were the springs and marshes of Ein Samonia, Ein Medora, Ein Sheikh, and Wadi Mitweh. Nearer to Merhavia were the Rub-el-Nazra springs and marshes, the Wadi Muweilli, the Afuleh "lake," and the Wadi Solim, interspersed with small tributary springs and seepage areas. The springs and marshes in the Ein Harod districts were even more numerous. On the west there is the large Ein Mayiteh spring and Wadi Zarain and the small Zarain tributary. The former is the source of an intricate system of irrigation canals, with the resulting breeding-places, while the latter merely spreads out into a shallow wadi, breeding *M. sergenti* in great abundance. Nearer to the settlement Ein Harod is the spring bearing that name, constituting one of the principal sources of the Jaloud River, which bisects the area, flowing due east and emptying into the Jordan. Along either side of this narrow valley, but principally on the southern side, are a series of springs which were the source of extensive swamps covering large portions of the arable land. On the south side going eastward are the chains of Rehania springs, the Ein Sakhne, Ein Asi, etc., and on the north side are the springs called

Ein Taboun, near Kumi. In addition the rapid fall of the Jaloud River made it favorable for a series of mills, each having its leaking mill run and impounded area of marsh land.

The first step toward control was to provide proper channels for the various springs, cleaning the edges of streams, and introducing some order in the irrigation. By channeling and alternating the flow of the streams and regulating the irrigation, more than two-thirds of the actual marsh area was eliminated. After that was accomplished, chemical control, principally with Paris green, was possible.

TABLE LVII

Average Monthly Incidence of Malaria in Merhavia and Ein Harod Districts

	Merhavia District*					Ein Harod District†				
	1922	1923	1924	1925	1926	1922	1923	1924	1925	1926
Average monthly incidence per thousand population	103	43.0	14.0	6.0	0.4	95	96.0	25.0	15.0	9.0
Per capita cost of all operations in P.T.	.....	22.8	3.4	5.8	5.8	.....	9.9	9.2	17.6	17.2

* In 1923, there were 6 villages, with a population of 1,430; in 1926, 18 villages, with a population of 5,307.

† In 1923, there were 9 villages, with a population of 2,425; in 1926, 11 villages, with a population of 3,397.

In the course of time permanent drainage of one form or another was installed. This constitutes, however, another phase of the subject and will be described in some detail later.

The results of the control efforts are again reflected in the malaria morbidity in the Jewish population and in the change of the blood and spleen indices in the Arab villages of these areas.

These are the results in the districts as a whole. In individual settlements, conditions vary considerably. In some, Nahalal, Balfouria, Merhavia, and Ein Taboun, there is practically no malaria. In Merhavia, for example, the monthly malaria incidence per thousand population for 1922–24, respectively, was 119, 49, and 4. In others, Afuleh, Ein Harod and Beth Alfa, there are periodic occurrences of small groups of cases due apparently to mosquitoes wandering in from the adjacent uncontrolled districts. These, and similar

occurrences elsewhere, can only be eliminated by the extension of effective control to the country as a whole.

The trend of the blood and spleen indices in the Arab villages in these areas is also of interest. The village Solim is typical of the Merhavia area, while Nuris is representative of the Ein Harod district.

The results are so striking that they require no comment. Of particular interest are the data in the Nuris village. Here no systematic treatment was used. The decrease in the blood and spleen indices is evidently due chiefly to progressive spontaneous recovery in the absence of reinfection.

TABLE LVIII

BLOOD AND SPLEEN INDICES IN NATIVE VILLAGES BEFORE AND AFTER CONTROL

Village	Year	Blood			Spleen		
		No. Exam.	No. Pos.	Per Cent	No. Exam.	No. Pos.	Per Cent Pos.
Solim	1923	78	35	44.9	58	30	51.7
	1924	33	5	9.4	52	14	26.9
Nuris	1921	26	6	23.1	33	32	97.0
	1922	56	13	23.2	56	44	78.6
	1924	32	0	0.0	32	15	46.9
	1925	111	5	4.5	111	27	24.3

DEMONSTRATION AREAS IN GALILEE

Similar control areas were organized in Lower and Upper Galilee. In Lower Galilee there were the districts Yabniel and Kinnereth, the former affected by Wadi Fejaz and its tributaries and the latter consisting of the settlements and villages around the Jordan. The latter is of special interest because it involves the control of stream-breeding and the results demonstrate the possibility of effective stream control under unusually difficult conditions.

The Kinnereth or Jordan Area is affected largely by breeding in the Jordan itself, but the situation is aggravated by numerous springs (more than one hundred) falling precipitously from the basalt rocks into the Jordan itself or into Wadi Fejaz, which ultimately empties into it. In this area nothing but continued control is possible, because we are dealing with a large perennial stream and precipitous tributaries. The results of the work and cost are, there-

fore, of special interest, because they represent as extreme conditions as one is likely to encounter in any country.

The Jordan River presents several problems in mosquito control. First in order is the river itself. Next are the precipitous wadis originating from springs in the cliffs. Finally, there are the mills, the mill channels, and the irrigation canals.

The river has two phases. In the spring when the Jordan is in flood, the flat areas are flooded and covered with ranunculi and potamogeton where *A. elutus* breeds in great abundance. In the late summer, when the Jordan is in ebb, large sections of the gravel beds are exposed, and there is prolific breeding of *M. sergenti.* In years of abundant rainfall, as in the winter of 1925–26, the river floods large areas of the plowed fields. These flooded areas develop all the characteristics of *elutus* breeding-marshes, thus greatly extending the areas to be controlled. In May and June, the Jordan begins to fall and continues to do so until the end of September. As the river falls first the gravelly shoreline and later large areas of the gravel bed are exposed. These exposed areas remain wet for considerable periods—long enough for the anopheles to complete its cycle. The uncovered gravel appears at uncertain intervals in places which cannot be predicted in advance. Consequently, repeated and constant inspection is required, particularly during the months of September and October when *M. sergenti* breeding is at its height. Often the breeding can only be detected by removing some of the gravel and exposing small pools of water. The larvae may then be seen attached to the gravel.

In so far as methods of control are concerned, the procedure depends on the conditions of the breeding-places and the seasons of the year.

In the spring, control consists in continuous cleaning of the islands of plankton in midstream aided by Paris green. In the flooded areas Paris green is the only effective measure. In the late summer, the problem of control is much more difficult. The best results are obtained by covering the exposed fine gravel with a layer of sand. This procedure is, however, laborious and, where sand is not available, costly. Paris green and cresol solution are most useful; the latter particularly gives good results in the control of breeding in gravel beds.

The difficulty of larval control in the Jordan can be fully appreciated only when one realizes that the breeding-areas recur at frequent and unexpected intervals in the entire length of the tortuous river, from the mouth of the Sea of Galilee. About 10 kilometers of this stream are actually under control.

The spring wadis breed especially *M. sergenti* and *M. superpictus*, and are controlled by cleaning the areas around the spring, and regulating their small wadis in order to allow a free unobstructed flow in a confined channel.

The mill and irrigation channels offer many difficulties. They start from the river or wadi and are carried at a low gradient along the slope of the hill. The result is that the downhill walls leak and

TABLE LIX

MALARIA INCIDENCE AND COST OF CONTROL IN KINNERETH DISTRICT*

	1920	1921	1922	1923	1924	1925	1926
Average monthly incidence per thousand population..........	94	14	37	28.0	27.0	21.0	33.0
Per capita cost of all operations in P.T......................	......	59	35	34.4	29.6	30.3	34.4

* In 1921, there were 10 villages, with a population of 915; in 1925, 9 villages, with a population of 1,010.

create a series of marshes. In addition there are the swamps caused by the run-off from the mill itself.

Repairs of such channels are out of the question, because they would be too costly. The easiest and most effective method of control consists in installing sluice gates at the head of the mill run and irrigation canals which render possible the closing of the mill and the drying of the marshes at regular intervals.

The results of these control efforts, limited during the last years entirely to mosquito eradication, are seen from the malaria incidence records in the Jewish villages bordering the Sea of Galilee and the Jordan River. Reliable statistics exist from the year 1920. In 1920, the monthly incidence per thousand population was 94. Control work was started in 1921. The malaria incidence in subsequent years is summarized in Table LIX.

This table gives the average monthly incidence each year since 1921, as well as the cost of control. This is a most expensive area

to control. But it should be noted that we are dealing with a permanent subtropical area in which there is a long breeding-season and a small population spread over an enormous breeding-area. The active breeding continues uninterruptedly during the long period from March to November, inclusive; when breeding of *A. elutus* ceases, that of *M. sergenti* begins. The control area is 10 kilometers long and 2 wide. In addition to these difficulties, the settlements are small and spread out along the banks of the stream, and highly infected nomadic Bedouin tribes camp all over the area. Under such conditions, the amount of reduction in malaria achieved and the constant low level at which it is maintained speak eloquently in favor of antilarval control. The cost of P.T. 30, or about $1.50, per capita cannot be considered excessive in view of the character of

TABLE LX

Malaria Incidence and Cost of Control in the Yabniel District

	1920	1921	1922	1923	1924	1925
Population	440	440	957	1038	1295	1363
Incidence per thousand	41.0	4.0	14.0	8.0	9.0	9.0
Per capita cost in P.T.	......	38.0	......	17.3	11.0	14.6

the settlements and of the large economic loss suffered by the inhabitants before control was started.

That these results are not accidental is demonstrated by the fact that in Jissr, a small settlement located under exactly the same conditions farther down the Jordan, malaria is continually epidemic and very severe. During the months of August to December, 1925, inclusive, there were in Jissr 32 *primary* cases among 40 people, an incidence of 80 per cent; whereas in the Kinnereth area, during the same period, there were the same number of primary cases in a population of 400, or just one-tenth as much malaria. Considerable epidemics occurred also at the same time in the farm Migdal and in the city of Tiberias where no control work was carried out. Thus, the limited malaria incidence in the Jordan area must be ascribed to anopheles control.

In the Yabniel District similar results have been obtained by similar measures. Here the chief problem consists in the control of

the numerous springs and wadis. Cleaning and Paris green are the principal methods employed. The effect is noted in the trend of the malaria morbidity since control was first instituted in 1921.

In this, as in the Kinnereth area, the incidence of malaria was lowered sharply during the first year of control. Subsequent control has maintained a constant low incidence at the same low level.

In Upper Galilee we also maintained two demonstration areas, one around Rosh Pina, the other around Metullah. Like the districts Hedera and Zichron, these present certain special features due to their proximity to the Huleh Marshes. The results will therefore be considered in the next chapter.

COMMENT

We believe that the demonstrations described in the foregoing prove that malaria control by antilarval measures is feasible. These demonstrations were conducted over a large area under a variety of conditions and over a period of several years. The results are, therefore, sufficient to establish the fact that successful control can be obtained by antimosquito methods, even under such difficult conditions as exist in the Kishon and Jordan areas. That the results are not fortuitous or due to other causes seems certain from the facts presented relating to spleen rates in non-control villages and epidemics in non-control or in unsuccessful control areas.

One important consideration arises: Is not the cost of the control excessive and would not other methods have yielded equally good results at lower cost? Another reasonable question that might be raised is whether other methods *would not have given good results* where antilarval measures have failed.

The first question is not easily answered. There is no standard norm of the minimal allowable cost of malaria control, nor is it possible to fix the degree of control that one should strive for. Elimination of infection is one thing, checking its manifestations is another. The former is apparently more costly, but how is one to estimate the cost of a low-grade infection by its effect on the vitality and productiveness of the population!

We believe that the average per capita cost expended in the various control areas is not excessive. In our cost calculations are in-

cluded all charges for actual control in the field, inspection, supervision, labor, and materials. Cost of permanent drainage is not included, because these undertakings, though desirable, are not always necessary for larval control. Our cost data indicate exactly what the annual per capita charge is for actual antilarval work.

Antilarval work is often considered expensive because of the cost of permanent drainage. Permanent drainage is not always a necessary prerequisite to control except in the case of extensive marshes that require reclamation, but in these areas the value of the reclaimed land often covers the cost of reclamation. But, even in the case of specific malaria drainage the per unit cost is not excessive, if properly estimated. A false impression is often obtained in such cases by calculating the cost on the basis of area reclaimed or of inhabitants immediately benefited. Neither computation presents an accurate idea of the cost. Drainage from the malaria standpoint does not always imply reclamation, just as reclamation of marshes does not imply freeing an area of malaria. In Palestine, particularly, the land area reclaimed is small in proportion to the habitable area benefited. Similarly, the population immediately benefited is not as a rule a correct criterion, because the very prevalence of malaria precludes the possibility of intensive settlement.

Even if the number of inhabitants actually benefited is used as a basis of computation, the cost is not excessive if spread over a period of years. The cost of drainage cannot properly be a charge for a single year. It should be reckoned on the same basis as other permanent works, and should be amortized over a period of years, according to the circumstances. Considered from this angle, permanent drainage is not costly and it may be more than worth while for any government to pass a loan for twenty years for such work.

To cite a concrete example: The drainage at Nahalal cost L.E. 13,000. On the basis of the area reclaimed, this reaches the large sum of L.E. 361.111 an acre. On the basis of the area benefited or made habitable, it is only P.T. 65 an acre. Similarly, if we compute the cost on the number benefited during one year the amount is L.E. 14 a head for the 437 Jews and 494 Arabs actually living there at the time the work was done. If, however, it is calculated on the

basis of twenty years' amortization, as it should be, the cost is only P.T. 70 per capita. And this does not take into account the fact that this work has stimulated the development of this area so that now a number of new settlements with an approximate population of 1,000 have been established within the sphere of influence of the former swamps, thus doubling population of the affected area.

The question whether other measures would not have been equally effective and less costly is easier to answer, in so far as Palestine is concerned. Our experiments in highly malarious areas with repeated systematic treatment have not yielded encouraging results. Reinfections occur regularly and the repetition of the treatment is more costly than mosquito control, even if we do not take into account the increased cost of medical care and the lowered productiveness of the inhabitants. This phase of the question will be discussed more fully in the next chapter.

An interesting phenomenon is the residual malaria, higher in certain districts than in others. In all districts, the general trend of the results is the same. During the first year of control, there is a sharp drop in the malaria incidence and then either there is a slight gradual reduction year by year or more generally the malaria rate fluctuates around the new level, which remains quite constant year after year. In some districts, the effect of the control is not felt until the second year, owing to the large number of relapses, which increase the total malaria incidence, but so long as the same effective control is carried out the new level remains fixed. This new point is different in different districts, but appears constant in a given district. For example, in the two oldest control areas—Yabniel and Kinnereth—the incidence in each area has now remained practically constant for four successive years. In Petah Tikvah, it has also remained more or less the same for the last four years. This residual malaria is apparently a function of the residual anophelism, which is different in the different districts. It has not been possible to work out the exact relationship on account of the fluctuation in susceptible population, varying degrees of susceptibility, fluctuation and movement of carrier (Bedouin) population, the variations in intensity of breeding at distances from the population centers, etc. There is no question, however, that where complete elimina-

tion of anopheles is not possible this residual malaria remains. It appears also that further reduction of malaria by a complete elimination of anopheles would, during the first year at least, cost the same as malaria control in a new area. We have tried this experiment in the Ein Harod District. There the monthly incidence of primary cases for 1923 and 1924 was the same, 9 per thousand, despite the progressive reduction of local carriers and the usual anopheles control (at least 90 per cent effective). In 1925, we tried to obtain more complete mosquito elimination by more rigid control of the irrigation canals and of the Jaloud River (the perennial stream bisecting the area). The monthly incidence of primary malaria was reduced from 9 to 4 per thousand population, but the per capita cost rose from 9.2 P.T. in 1924 to 17.6 P.T. in 1925. The new low level was maintained in 1926, but the per capita cost remained the same as in 1925. There is, therefore, apparently a limit beyond which it is too expensive to venture.

The average per capita cost of control in established areas also seems to be constant. Our experience indicates that effective mosquito control is possible in a new district or in the Jordan District, where the same work has to be repeated year after year at a cost of about 30 P.T. ($1.50) per capita (Metullah, 1924, Yazur, 1925, Kinnereth, 1923, 1924, 1925, etc.). After the first year the cost drops more or less quickly to about 10 P.T. ($0.50), where it remains constant, fluctuating more or less according to the difficulty of the local control problem. The average cost per capita for all the districts during the last four years has been remarkably constant—about 10 P.T.

CHAPTER IX

EXPERIMENTS WITH VARIOUS CONTROL MEASURES IN DISTRICTS WHERE ANTILARVAL CONTROL WAS UNSUCCESSFUL

In some of the control areas the conditions were such as to render antilarval measures impossible or ineffective. In the districts in Judea, the Valley of Esdraelon, Lower Galilee, the results obtained with the measures detailed in chapter viii were entirely satisfactory. This was not, however, the case in the districts Hedera and Zichron, in Samaria, and the area around the Huleh in Upper Galilee. In these sections the marshes were too extensive for chemical control and too difficult or too expensive to drain. Hedera was surrounded by a number of land-locked basins, each 20 or more hectares in extent. The Zichron area was dominated by the extensive Kabbara marsh—a coastal marsh covering an area of about 1,500 acres. The plain and foothills near the Sea of Merom were affected by the Huleh Marshes, several thousand acres in extent.

Except for a local control around a few individual villages, no impression could be made in these areas by antilarval control. Consequently, various other control measures were attempted. The primary and only aim was to bring about a reduction of malaria. The results of our efforts in these districts are, therefore, particularly instructive.

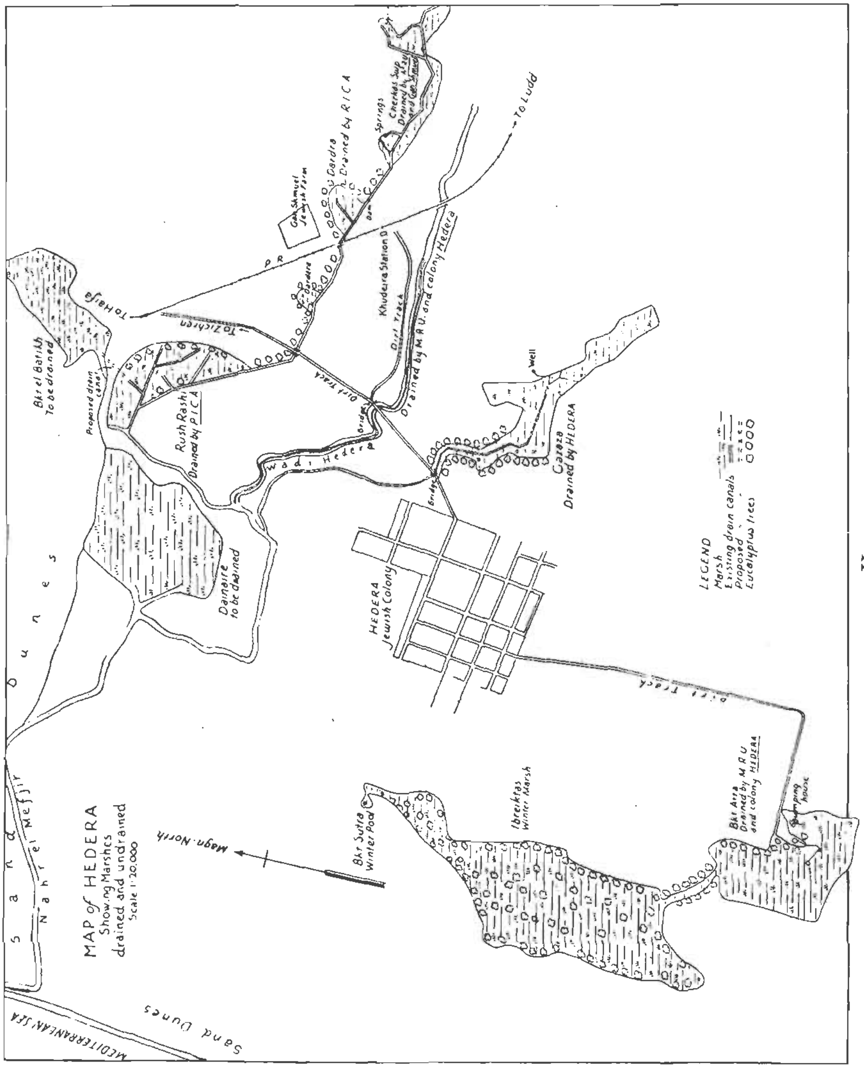
HEDERA

The Hedera area centers around the settlement of Hedera, situated on an elevation which is within flight range of anopheles from a series of marshes. The location of the main settlement and its relation to the surrounding swamps are shown in the accompanying map.

Along these marshes are several groups of semipermanent, pastoral Bedouins. One group moves to and fro on the dunes west and northwest of Hedera, along Birket Atta and Ibreiktaz. Another group lives near the Dameira swamp, north of Hedera. Still another

group lives in and near the Birket Batikh, at the northeast corner of the area. Cherkas village on the Cherkas swamp is on the eastern

MAP XI



HEDERA

boundary, while the Baika group live on the southern side between Hedera and Gazaza.

The worst marshes in the area are Birket Atta, Dameira, and

Birket Batikh. In the Wadi Khudeireh, Cherkas swamp, and the remaining portion of Gazaza, larval control presented no difficulty after drainage and regulation had been completed. Ibreiktaz usually dries early in May and presents a serious breeding problem only in years of exceptionally large and voluminous rainfall. The remaining marshes are, however, too extensive for effective larval control, and breeding of *A. elutus* is unusually prolific, especially in the first and last named.

The methods of control employed at Hedera were threefold. Larval control was initiated in those marshes where such control was feasible (Gazaza, Wadi Khudeireh, Safra, Cherkas). Systematic daily destruction of adult mosquitoes was introduced in the tents

TABLE LXI

RESULTS OF TREATING BEDOUIN POPULATION IN THE VICINITY OF HEDERA, 1925
(Children under Thirteen)

Months	Year	Blood			Spleen		
		No. Exam.	No. Pos.	Per Cent Pos.	No. Exam.	No. Pos.	Per Cent Pos.
March–April.....	1925	174	37	21.2	117	69	60
May–June......	1925	89	17	19.1	51	36	70

near Birket Atta, as well as in the houses of the settlement (during the months of heavy breeding, one or two persons were employed solely for daily mosquito destruction). In addition to mosquito destruction, mass treatment was organized. Both the Jewish and the Bedouin population were treated during March and April, 1925, before the onset of the spring epidemic. After the examination of the various sections of the population two special orderlies were detailed for the treatment. These orderlies visited each village or camp twice daily and administered quinine directly to each individual. The treatment consisted of 2 grams of quinine daily for each adult and proportionate doses for children, for a period of ten days.

Examinations were made of groups of children shortly before and six weeks after the treatment. The results given in Table LXI indicate that its effect was negligible. Whether the orderlies were at fault or the people, it was clear that mass treatment by native

orderlies was ineffective. Subsequent observations convinced us that the only way to make any impression was to administer quinine solution under the supervision of a physician.

TABLE LXII

MONTHLY INCIDENCE OF MALARIA—1922–25

(Per Thousand Population)

	Total*	Relapses	New	Total	Relapses	New	Total	Relapses	New	Total
	Hedera									
	Population, 698 in 1922	Population, 650 in 1923			Population, 764 in 1924			Population, 906 in 1925		
Jan.	......	49	4	53	17	3	20	11	6	17
Feb.	31	37	0	37	40	0	40	14	6	20
Mar.	43	29	0	29	30	1	31	13	4	17
Apr.	23	43	0	43	53	3	56	7	1	8
May	30	26	2	28	12	6	18	9	1	10
June	45	49	54	103	21	25	46	9	29	38
July	94	61	90	151	36	39	75	27	75	102
Aug.	80	68	16	84	32	14	46	49	59	108
Sept.	64	28	7	35	30	7	37	30	29	59
Oct.	36	33	4	37	18	4	22	13	13	26
Nov.	29	25	4	29	18	4	22	27	11	38
Dec.	25	43	8	51	12	5	17	25	5	30
Average per mo.	47	41	16	57	27	9	36	20	19	39
	Gan Shmuel									
		Population, 39 in 1923			Population, 41 in 1924			Population, 47 in 1925		
Jan.	......	147	30	177	67	0	67	10	0	10
Feb.	......	175	0	175	44	0	44	143	57	200
Mar.	......	347	0	347	24	0	24	66	0	66
Apr.	......	228	0	228	75	0	75	83	17	100
May	......	25	25	50	50	0	50	33	17	50
June	......	114	28	142	125	100	225	150	83	233
July	......	95	34	119	111	56	167	233	133	366
Aug.	......	23	47	70	75	75	150	200	33	233
Sept.	......	71	0	71	100	50	150	133	60	193
Oct.	......	27	0	27	93	47	140	200	0	200
Nov.	......	0	0	0	150	25	175	117	33	150
Dec.	......	24	0	24	125	25	150	145	36	181
Average per mo.	......	106	13	119	87	31	118	126	28	164

* The lower figures for 1922 are probably due to incomplete reporting, since this was the first attempt to gather morbidity data on malaria.

These combined measures had little effect on the course of malaria in Hedera in 1925. Table LXII shows the malaria incidence in Hedera and Table LXIII the blood and spleen indices in the Bedouin population.

The entire area suffered from a severe epidemic of malaria during 1925. The extent of the epidemic was even greater than that of 1924. Its severity may be gauged by the high blood index among the Bedouin children. Obviously, the various measures employed were not adequate to check the epidemic, although it was undoubtedly much less severe than it might have been had nothing been done, particularly since that year Ibreiktaz did not dry until July and was breeding heavily.

TABLE LXIII

BLOOD AND SPLEEN INDICES IN THE BEDOUIN POPULATION BEFORE AND AFTER THE EPIDEMIC SEASON*

	Blood Index			Spleen Index		
	No. Exam.	No. Pos.	Per Cent Pos.	No. Exam.	No. Pos.	Per Cent Pos.
May–June, 1925	89	17	19.1	51	36	70.0
Dec., 1925–Jan., 1926	95	67	70.5	95	84	88.4

The experiment was not abandoned, but was carried out more systematically during the winter of that year (1925) and the spring of the following (1926). A special physician (Dr. I. Weitzman) and two orderlies were detailed for an intensive examination and treatment of the entire population. Examinations were made of all the villages and in so far as possible of the nomad population in the districts. Examinations were made in December–January, and were followed by treatment. Re-examinations were made in February after the completion of the first course of treatment, consisting of 2 grams of quinine solution daily for five days, and proportionate doses for children. A third examination was made in April, followed by a second course of treatment. Re-examinations were then made in May, October, and January. The last examination was again followed by a course of treatment, in March and April of 1927, of 2 grams of quinine per adult daily for ten days.

The effect of the treatment was observed in repeated examina-

TABLE LXIV

BLOOD AND SPLEEN INDICES DURING VARIOUS EXAMINATIONS PRIOR AND SUBSEQUENT TO TREATMENT

(Children under Thirteen)

Sex	1st Exam. Dec. 1924 Jan. 1925				2d Exam. Feb., 1926*				3d Exam. Apr., 1926†				4th Exam. June, 1926‡				5th Exam. Oct., 1926				6th Exam. Jan., 1927			
	Blood		Spleen		Blood		Spleen		Blood		Spleen		Blood		Spleen		Blood		Spleen		Blood		Spleen	
	No. Pos.	%	No- Pos.	%	No. Pos.	%	No. Pos.	%	No. Pos.	%	No. Pos.	%	No. Pos.	%	No. Pos.	%	No. Pos.	%	No. Pos.	%	No. Pos.	%	No. Pos.	%
Male........	45	70	57	88	20	34	50	85	14	27	41	80	9	20	35	73	17	35	46	94	13	25	42	79
Female......	28	54	45	86	5	13	25	63	5	12	25	60	2	6	23	64	4	11	28	76	5	12	27	63

* One month after completion of first treatment.

† Two months after completion of first treatment.

‡ One month after completion of second treatment.

tions. The data are summarized in Table LXIV. It is clear that the treatment brought about a decided reduction in the carrier rate. The lowest rate was after the second treatment and just before the onset of the epidemic period (June). Subsequent to that, the blood index increased but remained decidedly below that found during the first examination.

The direct effect of the method of the treatment on the various parasites in the peripheral circulation is shown in Table LXV. The results are in conformity with the experience of other investigators. Quartan malaria yielded to treatment only with difficulty and gave a high percentage of relapses. In the other forms, the blood was

TABLE LXV

EFFECT OF TREATMENT ON DIFFERENT PARASITES

Types of Malaria	Number Observed	Negative on Second Day		Positive After				Relapse After			
				2 days		3 days		1st Treatment		2d Treatment	
		No.	Per Cent	No.	Per Cent	No.	Per Cent	No.	Per Cent	No.	Per Cent
B.T.	27	13	48.1	12	44.4	2	7.5	14	51.5	8	30.0
M.T.	49	33	67.3	12	24.5	5	10.0	19	38.7	4	8.2
Quartan	14	0	0.0	11	78.6	3	21.4	9	64.3	9	64.3

freed from parasites on the third day in more than 90 per cent of the cases. In five days the peripheral blood contained no parasites. Relapses were common after the first treatment in benign and malignant cases. Benign malaria gave a higher percentage of relapses even after the second treatment.

It is evident that although repeated treatment did reduce the parasite and spleen rates, they still remained too high to modify the course of an epidemic. The treatment was carried out as carefully as possible. A special physician was assigned to the task. Quinine was administered twice daily by the physician himself, or under his personal supervision. The effect of the treatment on the peripheral parasites in the cases receiving the full course of treatment indicates that the method employed was as effective as any other. However, the object of controlling the disease by reduction of carriers was not achieved.

The reasons for the failure are obvious. The first reason is that quinine is not a sterilizing drug. The resistance of benign tertian and quartan malaria to treatment is well known and is emphasized again by the data shown in Table LXV. The other reason is that mass treatment of a native community is a matter of great difficulty. Even in the villages there are various complications: many of the villagers work out or sleep in the field, some hide, others are here one day and there the next. The result is that a smaller or larger part of the population remains untreated, while of the treated portion of the population there remains a large residue of cases resistant to treatment. This residue of carriers constitutes the reservoir of parasites, and when conditions are favorable a new epidemic destroys all the benefit derived from the intensive treatment.

It is difficult to gauge the effect of this treatment on the course of malaria in 1926, which was unfortunately not a favorable year for unequivocal conclusions. The distribution of the rains during the winter 1925–26 was favorable in so far as the coastal marshes were concerned. As a result, despite the larger rainfall, Birket Atta had half as much water as in 1925, and was dry by the end of June, whereas in 1925 it was not dry until the end of August. Ibreiktaz was dry in April instead of July. Consequently, the anopheles incidence in 1926 was only one-fourth as great as in 1925, and the invasion ceased a month earlier.

This combination of circumstances resulted in a marked decrease in the malaria incidence in Hedera and vicinity. But it is impossible to establish how far the reduction was due to the decrease in the number of carriers and how far to the low prevalence of mosquitoes.

A more adequate test is offered by the experience in 1927. The rain conditions during the winter 1926–27 were more comparable to those in 1925. Birket Atta was twice as large as in 1926. Ibreiktaz did not dry until the end of May. The mosquito incidence corresponded to that of 1925 more closely.

The carrier rate was, however, much lower than in 1925. After the examinaion of January, 1927, the entire Bedouin population was again treated. All Bedouins working in the Atta orange groves were constantly quininized during May, June, and July. Nevertheless, there was a severe epidemic of malaria in Hedera.

The severity of the epidemic is shown by the malaria morbidity in Hedera as well as by the rise in the blood and spleen indices in the Bedouin population. Despite the combined methods of treatment of carriers and the systematic daily destruction of adult mosquitoes in houses and tents, the mass invasion of anopheles brought

TABLE LXVI

Incidence of Malaria in Hedera—1926–1927*

(Per Thousand Population)

Month	1926			1927		
	New	Relapses	Total	New	Relapses	Total
January	7.3	32.6	39.9	3.0	7.6	10.6
February	8.4	35.8	44.2	1.5	8.3	9.8
March	6.3	32.4	38.7	2.3	12.8	15.0
April	3.7	25.9	29.6	1.5	10.9	12.4
May	3.5	16.8	20.3	2.1	17.9	20.0
June	0.9	9.0	9.9	30.0	20.0	50.0
July	34.2	31.6	65.8	84.4	78.1	162.5
August	8.1	17.8	25.9	21.2	33.8	55.0
September	8.1	19.5	27.6	5.6	31.2	36.8

* The effect on the Bedouin population is shown by a comparison of the blood and spleen indices for January and September, 1927, respectively.

TABLE LXVII

Blood and Spleen Indices of Hedera Bedouins, 1927

(Children under Thirteen)

Month	Blood			Spleen		
	No. Exam	No. Pos.	Per Cent Pos.	No. Exam	No. Pos.	Per Cent Pos.
January	96	18	18.7	96	69	71.9
September	31	15	48.4	31	28	90.3

about a severe epidemic in the entire area. The difference in the two years is strikingly demonstrated by the morbidity figures for the epidemic months June–August, inclusive.

The epidemic affected both groups of the population equally. The low carrier rate in the Jewish settlement did not operate toward a lower morbidity any more than did the relatively large reduction of the number of carriers in the Bedouin population. From the progress of the epidemic it was evident that there was a gradual and steady diffusion of infected mosquitoes from the Bedouin camps to

the outskirts of the settlement, and from there to the settlement itself. The workmen living in the periphery came down first; later, the entire population was involved, cases appearing in all sections of the village. It would seem that with a large influx of anopheles, nothing less than an approximately complete sterilization of the population can give the same degree of protection as effective mosquito control. But even in a non-epidemic area such sterilization is not an easy matter in benign tertian malaria.

ZICHRON

The problem in the Zichron area is somewhat different from that in Hedera. In this area the dominant factor was the Kabbara marsh, and consequently larval control of any kind was of little value. Emphasis was laid, therefore, on systematic destruction of adult mosquitoes and thorough treatment of cases. The village of Zichron is located on a hill 2.25 kilometers from the swamp. There, systematic mosquito destruction served the purpose admirably, although a small number of primary cases usually occurred during the last four months of the year.

In Benjamina, the other important settlement in this area directly influenced by the Kabbara, the situation was quite different. This settlement is located 1.5 kilometers south of the marsh. In addition there are several minor breeding-places south and east of the settlement. The population consists of about 200 workmen and 240 permanent inhabitants. The workmen live chiefly in barracks, while the settlers live in well-built houses. The presence of a full-time physician, employed by the community, assures early detection and treatment of cases. Threefold measures were used to bring about a reduction in malaria: larval control around the settlement, systematic destruction of adult mosquitoes in houses and stables, and prompt and effective treatment of cases. Until 1927, no appreciable effect was produced on the incidence of infection. In 1926, there was a severe epidemic, especially among the workmen. It was not until 1927, when the drainage work at Kabbara had reached a point where larval control was possible, that a not unimportant reduction in the malaria incidence was brought about. A comparison of the incidence of 1926 and 1927 is presented in Table LXVIII.

It seems apparent that in settlements adjacent to intense anopheline-producing areas marked improvement in the malaria condition cannot be brought about even by the combined measures of destruction of imagos and effective treatment of local cases. Despite the fact that the rainfall and resulting breeding-places were greater in 1927 than in 1926, the reduction of anopheles as a result of larval control in the reclaimed Kabbara marsh was considerable.

TABLE LXVIII

INCIDENCE OF MALARIA IN BENJAMINA—1926–27*

(Per Thousand Population)

Month	1926 Population, 320			1927 Population, 420		
	Rel.	New	Total	Rel.	New	Total
Jan.	55	4.0	59.0	81	3.0	84.0
Feb.	54	0.0	54.0	56	3.0	59.0
March	37	0.0	37.0	60	5.5	65.5
April	61	0.0	61.0	50	3.0	53.0
May	51	3.0	54.0	60	0.0	60.0
June	74	14.0	88.0	24	4.7	28.7
July	28	134.0	162.0	29	98.0	127.0
Aug.	92	43.0	135.0	10	31.0	41.0
Sept.	49	36.0	85.0	31	12.0	43.0
Oct.	80	5.5	85.5	5	10.0	15.0
Nov.	50	20.0	70.0	5	10.0	15.0
Dec.	34	15.6	49.6	....	....	....
Average	....	....	78.3	....	....	53.7

* Incidence of new cases, Jan.–Sept., 1926, 227 per thousand, incidence of new cases, Jan.–Sept., 1927, 145.7 per thousand.

There is little room for doubt that the decrease in the malaria incidence was a result of this reduction in anopheles prevalence.

HULEH AREA

In the Huleh area the anopheline population is so dense that quininization was the only measure applicable. At first quinine was distributed daily in 5-grain doses to all the inhabitants of Yessod. At the same time efforts were made to treat promptly all cases as they developed. The result has been the practical elimination of blackwater fever, but, as the figures showing the average monthly incidence of malaria at Yessod indicate, the degree of infection has remained practically unchanged. In 1922, in which the reporting was incomplete, the incidence was 4.7; in 1923 it was 8;

and in 1924, 7. In 1925 and 1926, free quinine was furnished the resident physician for systematic treatment of all patients. Both the medical care and the drug were given free, but no appreciable change was noted in the malaria rate. An examination of the children in Yessod during September, 1927, at the end of the first epidemic period, gave a blood index of 16.6 and a spleen index of 43.3. This blood index is unusually high for a Jewish settlement and is, therefore, significant of the condition.

The experience in the village Rosh Pina is particularly interesting. This settlement is at the extreme periphery of the area, some 12 to 13 kilometers from the Huleh. Local breeding-places are few and easily controlled. Anopheles, as well as malaria, are practically absent throughout the year. Toward the end of October, an anopheles invasion begins and is followed during November and December by an outbreak of malaria. In 1925, intensive mosquito destruction was started early, and though cases occurred they were few in number. In 1926, the destruction was quite as effective, and yet the epidemic was much more severe. The general trend of malaria in Rosh Pina is shown in Tables LXIX and LXX. Practically no new cases and relatively few relapses occur throughout the year. In November there is a sudden outbreak more or less severe in character, but differing in intensity each year.

The results recorded in the foregoing do not compare favorably with those obtained by antilarval measures. Every effort was made to carry out the work as systematically as was possible under the circumstances. Treatment of carriers and destruction of adult mosquitoes were used alone and in combination with minor antilarval measures. A general improvement in condition has undoubtedly been brought about, both in the morbidity and in the severity of the disease. Blackwater fever, once so prevalent, is now an unusually rare occurrence, and the malaria mortality is negligible. But the endemicity and epidemicity of the disease still remain high, as high as they were in the districts where effective larval control has been carried out before such measures were undertaken.

In general, treatment of carriers has not proved as effective as one might have expected from general considerations. The superficial impression we gained when the work was first started was

that Palestine was particularly suited for control by mass treatment of the population along the lines carried out by Bass in Mississippi. The country is small and compact; the mass of the people are too poor and unintelligent to assist in other measures; consequently, it seemed that the quickest and best way of checking the disease

TABLE LXIX

Primary Infections in Rosh Pina—1923–25

(No. of Cases)

Year	Average Population	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1923	514	0	0	0	0	0	0	0	0	0	0	6	21
1924	575	2	0	0	0	0	0	0	0	0	0	12	14
1925	539	0	0	0	0	0	0	0	0	0	0	2	7

TABLE LXX

Malaria Incidence in Rosh Pina—1926–27

(Per Thousand Population)

Month	Population, 614 in 1926			Population, 630 in 1927		
	New	Relapses	Total	New	Relapses	Total
January	....	....	....	18	9	27
February	....	....	....	2	6	8
March	0	2	2	2	6	8
April	0	3	3	0	6	6
May	0	3	3	0	6	0
June	0	5	5	2	13	15
July	6	2	8	3	13	16
August	0	2	2	5	5	10
September	3	3	6	....	....	....
October	5	0	5	....	....	....
November	100	13	113	....	....	....
December	118	18	136	....	....	....

should be mass destruction of the plasmodia in the human host. The results of the first experiment, together with a more careful study of the social conditions of the country and the relative distribution of the parasite carriers, cast doubt on the probable success to be achieved by this method.

As for the value of killing adult mosquitoes in houses, the epidemiologic experience in Hedera, Benjamina, and particularly in Rosh Pina and Herzlia, go to refute James' hypothesis, that infected

anopheles stay in the houses where the infection is contracted. Here we have severe epidemic outbreaks in places having either an extremely low (Hedera) or negative blood and spleen indices (Rosh Pina). Moreover, in Rosh Pina, one does not note the usual interval of one month between the anopheles invasion and outbreak of cases. The first cases appear in November about two weeks after the mosquito invasion begins. This phenomenon can be accounted for only by the assumption that there are infected mosquitoes among the invaders. This assumption has been confirmed by dissections of mosquitoes taken in cellars and stables in Rosh Pina. Of 80 *A. elutus* dissected 3, or 3.7 per cent, were found to be infected, two with sporozoites.

In order to study this and other related problems more thoroughly, a research station has been established at Rosh Pina by the department of hygiene of the Hebrew University. Among other things, systematic dissections are being made of anopheles taken in houses and stables at different seasons of the year. The results thus far are illuminating. Three distinct facts stand out. Between June 1 and October 15, 15 out of 450 *A. elutus* from houses were found to be infected (3.3 per cent), and none of the 95 taken in the stables. Between October 15 and November 15, 120 *A. elutus* from houses yielded only 1, while 59 from stables contained 2 infected specimens. These results indicate that *A. elutus* behaves differently at different seasons, and infected mosquitoes do leave the houses. *M. superpictus* differs from *A. elutus* in that infected specimens were found in stables even during the active breeding-season. During July and August, dissection of 140 specimens from stables and 45 from houses showed two infected insects in each batch. The numbers are too small to make comparisons, but the relatively high percentage of infected *M. superpictus* from stables is significant. Both infected mosquitoes taken in the stables contained sporozoites.

These results, though preliminary in character, confirm our epidemiologic observations and are contrary to the assumption advanced by James that infected anopheles stay in houses. They tend to explain, however, the unsatisfactory results obtained by systematic mosquito destruction. The destruction of adult mosquitoes helps, but evidently many are killed only after the mischief has been

done, that is, after they have infected one or more of the inhabitants. Both our epidemiologic observations and actual dissections indicate that the observation made by James is perhaps locally but not universally applicable.

CONTROL BY QUININE PROPHYLAXIS

Another phase of the Koch method, greatly in vogue before the World War, is the prevention of malaria infection by the ingestion of small quantities of quinine daily, biweekly, or at other regular intervals. The underlying idea was that the constant presence of small quantities of quinine in the circulation would prevent infection by the destruction of the sporozoites as they are injected. The war experience has shown that this method was practically useless; practical results fell short of the theoretical promise.

Our own experience under carefully controlled peace conditions confirmed that of the war. We have experimented with quinine prophylaxis under a variety of conditions and with different doses. It is not possible to say whether a certain number of infections were aborted and, if so, how many. But it is quite clear that it did not prevent infections, because many cases appeared, during the administration of quinine, among people thoroughly quininized, and many more developed an attack during the first two or three weeks following its suspension. Some of our data are briefly summarized in Table LXXI.

It is evident from these results that whatever the method employed, and despite the extreme care always exercised in the distribution of the drug, the number of cases was considerable. Most conclusive is the fact that the cessation of quinine at a time when new infections could be definitely excluded was always followed by an outbreak of cases beginning about five days, and continuing up to three weeks, after the quinine was stopped. The quinine obviously maintains the infection in a state of latency, and as soon as the pressure is removed the infection develops.

The ability of quinine to maintain a latent infection is illustrated by the experience in Athlit. This place was highly malarious, and there were about 200 workers employed in installing a salt works. To keep up the working strength of the men, a special per-

son was employed to distribute quinine. Ten grains were given daily to each worker during the months of August to November, inclusive.

TABLE LXXI

EXPERIENCE WITH QUININE AS A PROPHYLACTIC MEASURE

Place	No. of Inhabitants	Length of Time Administered	No. of New Cases	Time of Appearance of Cases
Group 1. Administration of 0.5 gm. daily—Children Proportional Doses				
Kinnereth	300	May 1, 1921–Jan. 1, 1922	20	May 1, 1921–Jan. 10, 1922
Hedera workmen	140	May–Aug., 1923	41	June–Aug., 1923 (no cases in May)
Group 2. Administration of 0.66 gm. Daily				
Wadi Belames	35	Nov., 1921–Jan. 15, 1922	7	Nov., 2 cases; Dec. and Jan. 5
Migdal Camp	250	Sept., 1921–Jan., 1922	14	Oct., 1921–Jan., 1922
Kinnereth	320	Sept.–Dec. 15, 1923	24	Sept., 3 cases; Oct. to end Dec., 1923, 21 cases
Kinnereth	300	Sept.–Dec. 15, 1924	37	Sept., 3 cases; Oct. to end of Dec., 1924, 34 cases
Hedera workmen	200	May 15–Aug. 30, 1924	34	May, 2 cases; June–Sept. 15, 32 cases
Hedera Orphanage	125	May–Sept. 15, 1924	68	May, 1 case; June–Oct., 67 cases
Gan Shmuel	40	May–Dec., 1924	15	May, 3 cases; June to end of Dec., 12 cases
Athlit	166	July–Dec., 1922	138	July–Dec., 1922
Yazur	220	May–June 15, 1924	18	May, 2 cases; June, 16 cases
Nuris (infants)	12	May, 1922–Jan. 26, 1924	11	Jan. 29–Feb. 15, 1923, 11 cases
Nahlat Jacob	250	June 20, 1925–Aug. 2, 1925	44	June to end of Aug., 1925
Mahanaim*	......	......	......	......
Group 3. Administration of 1 gm. Daily on Three Successive Days in the Week				
Gan Shmuel	50	May–Dec., 1923	5	May to end Dec., 1923
Shuni	60	May–Dec., 1923	14	May–Dec., 1923
Shuni	60	Dec., 1924	5	May–Dec., 1924
Zurghanieh	50	Dec., 1923	11	May–Dec., 1923
Zurghanieh	50	Dec., 1924	6	May–Dec., 1924

* Prophylactic quinine was started October 28, 1924, and continued up to December 18, 1924; half of the inhabitants did not receive quinine regularly. On November 13, three cases occurred among those who received quinine.

On December 6, quinine was stopped for 4 days and the men examined. Parasites were found in the blood of 30 out of 112 men examined, and 47 had enlarged spleens. Only 24 men gave a negative malaria history, and malaria parasites were found in 5 of them.

The reason for the lack of correspondence between theory and practice was the gap in our knowledge of the action of quinine *in vivo* on the parasite. Recent experimental evidence has filled some of these gaps and shown that the action of the drug is by no means so simple as was previously imagined. This newer information accounts for the failure to obtain good results with quinine prophylaxis. As is usually the case, the theory was wrong, because it was based on insufficient knowledge.

ACTION OF QUININE ON THE MALARIAL PARASITE

First of all it appears that quinine effects different varieties of plasmodia differently. The trophozoite forms of *P. vivax* are less affected by the alkaloid than are those of *P. falciparum* (Acton Gilchrist, Kligler and Weitzman *et al*). On the other hand, gametes of *P. vivax* are more sensitive to quinine than are those of *P. falciparum* (Mayne, Wenyon, Kligler and Ashner). This difference in susceptibility has not been proved experimentally *in vitro*, but is inferred from the observed facts that (1) *P. vivax* infections are cured with greater difficulty and give a much greater percentage of relapses than do those of *P. falciparum*, and (2) anopheles fed on quinine-treated patients infected with *P. vivax* do not become infective, whereas when fed under similar conditions on patients infected with *P. falciparum* they do become infective. These observations establish a partial selective action of the drug on the various stages of the two parasites.

An observation of greatest importance in this connection is the one made recently by Yorke and Macfie. These authors found that individuals under the influence of quinine failed to develop infections when the parasites were transferred directly from the blood of another individual. However, individuals receiving the same dose of quinine, and subsequently infected by a mosquito, develop the infection. In other words the *trophozoites are susceptible to the toxic*

action of quinine while the sporozoites are not. These authors conclude that their

> observations on the value of quinine prophylaxis showed that administration of the drug before infection is useless; that its administration must be continued for at least ten days after the infecting feed to prevent infection from developing, and that the daily dose given has but little influence. It is concluded from these observations that quinine has little if any action on sporozoites, and that the mechanism by which development of infection is prevented is similar to that by which a cure is effected.

Summarizing the new additions to our knowledge we find:

1. Sporozoites of malarial parasites are not sensitive to quinine.
2. Trophozoites of *P. vivax* are more resistant to quinine than are those of *P. falciparum.*
3. Gametes of *P. vivax* are, and gametes of *P. falciparum* are not, sensitive to quinine.

With the help of this additional knowledge, it is possible to understand why the theoretical basis for the use of quinine in the prevention of malaria infections was not borne out by the actual experience.

Once it becomes clear that quinine does not act as a prophylactic agent (a substance preventing infections), then the whole point of view must be changed. The so-called *prophylactic* administration of quinine is in reality a method of *abortive treatment* of an infection before the physical manifestations of active symptoms. What value, if any, is there then in quinine as an aid in the control and prevention of malaria epidemics? Put in this way, the facts enumerated above may form a basis for rational utilization of quinine as one of the possible aids in malaria control.

If quinine cannot prevent infections, it is still today the most effective specific drug for the treatment of malaria. One use for quinine then is to abort a possible infection in people from uninfected areas who have temporarily entered infected areas, by means of therapeutic doses of the drug, that is quininization for two weeks after departure from the infected area. Another possible use for quinine is the continuous quininization of *carriers* of gametes of *P. vivax* in order to render them non-infective to the mosquito. This involves a shifting of emphasis from the person exposed to infection to the *person causing the infection.* A third possible use is mass abor-

tive treatment of a whole population experiencing an epidemic during the period of its greatest intensity; such mass treatment should stop promptly after the subsidence of the epidemic and be continued only in proved carriers.

It is clear, however, that at best quinine administered in this way is no more than a palliative, and can be regarded only as an aid to but not as a method of control. Some measure of prevention may be achieved by quininization of *P. vivax* gamete carriers; but in this case the problem reduces itself to that of the mass treatment of carriers, the difficulties of which have been discussed in the foregoing. Quinine in a prophylactic sense is a misnomer. There is evidently no such thing as quinine prophylaxis, because the drug does not prevent an infection.

APPENDIX

TYPICAL DRAINAGE WORKS OF A PERMANENT CHARACTER

Coincident with the organized antimalaria campaign and largely as a result of it, various colonizing agencies have undertaken reclamation and antimalaria drainage. The first extensive project was carried out by the Jewish National Fund (J.N.F.) and was begun toward the end of 1922. Since then important works have been carried out by the Palestine Jewish Colonization Association (Pica), by the American Zion Commonwealth (Amzec), and by the Palestine Salt Company. Several minor projects have been completed by the Malaria Research Unit in co-operation with the settlers.

Most of the drainage was carried out along standard lines. However, the various enterprises cover a sufficient variety of problems and methods to make a comparison interesting and instructive. Since several of the works have functioned for three or four years, evaluation is now possible.

It will suffice to mention briefly the significant works completed, discuss the comparative value of the different methods under climatic and soil conditions prevailing in Palestine, and then describe some of the typical and more important works in detail.

EKRON AREA

Beginning with the south, the Wadi Surar area is now practically free from malaria, owing partly to mosquito control in the wadi, carried out by the Medical Research Unit, and partly to the permanent drainage of (1) the spring near Hulda by the Jewish National Fund, (2) the Melat Swamp by the Malaria Research Unit, in co-operation with the villages Ekron and Naaneh, and (3) Ein Koreh by the Malaria Research Unit and the settlement Rishon Le Zion. The monthly malaria incidence (new cases and relapses) in this area is now less than one per thousand of population.

PETAH TIKVAH AREA

In the Petah Tikvah area work of a permanent character has been carried out almost entirely by the Malaria Research Unit, in co-operation with the villages concerned. The Wadis Abu Lejja, Ishkar, and Adas, all tributaries of the Auja, have been regulated, and the plans completed for the drainage of the last of these tributaries—Wadi Musrara. With the drying of this wadi the requisite permanent work in this area will be finished. The American Zion Commonwealth has improved the old Roman drain and thus completed the drainage of Birket Katura, near the new settlement Herzlia. The only important swamp which will remain in this region after the drainage of Wadi Musrara is the one at Ras el Ein, which is outside the Petah Tikvah Area.

HEDERA AREA

The Hedera area abounds in marshes. Much work of a permanent character has already been done, but much still remains to be done. Hedera itself had drained the great part of Gazaza Swamp in 1922, and in 1925 the village Zeita and the settlement Hedera completed the work, under the direction of the Malaria Research Unit. Cherkas Swamp and Wadi Khudeira have been drained by the Malaria Research Unit, in co-operation with Gan Shmuel and Hedera. In Birket Atta a centrifugal pump has been installed for the removal of the water for irrigation. The Pica has drained the Rush-Rushek Marsh. Four marshes yet remain: Birket Atta, Ibreiktaz on Pica land, Helu Swamp on Arab property, and Birket Batikh on government property.

ZICHRON AREA

In Zichron the Pica is now completing the drainage of the extensive marshes at Kabbara and the Zerka and its tributaries, while the Malaria Research Unit is doing work at Hadeidoon, a seepage area in this region.

ATHLIT

In Athlit the extensive coastal marshes have been eliminated by the Palestine Salt Company.

KISHON AND ACRE PLAINS

In the Kishon and Acre plains along the coast, the Kishon marshes near Haifa are being drained by the government and plans have been prepared by the Haifa Bay Development Company to drain the Fuara marshes on the north side of the Kishon and the Khurdany-Namein marshes near Acre. A certain amount of work has already been done on the Fuara and Khurdany marshes.

WORK ACCOMPLISHED IN THE COASTAL PLAIN

It is of interest to note that all the work of a permanent nature along the coast, with the exception of the Kishon marshes near Haifa, has been done by Jewish agencies and that of the remaining marshes only one is on Jewish property. Nahr Rubin and Birket Ramadan, the largest remaining coastal marshes, are on property belonging to or claimed by the Wakf. The Ras el Ein, Hawarith, and Helu swamps are on Arab property, while Biket Batikh is on Giftlik or government land. These render uninhabitable large areas which could otherwise become closely settled prosperous communities.

VALLEY OF ESDRAELON

In the Valley of Esdraelon the amount of work done and the results achieved are amazing. The greater part of the drainage has been done by the Jewish National Fund, but substantial projects have been carried out by the American Zion Commonwealth, the Malaria Research Unit and the town of Beisan. As a result of this work the whole of the valley, which was very sparsely settled and,

until 1923, one of the most malarious sections of the country, has been brought to a point where malaria control is a relatively simple matter.

FIG. 20.—Ein Sheikh, near Nahalal before drainage

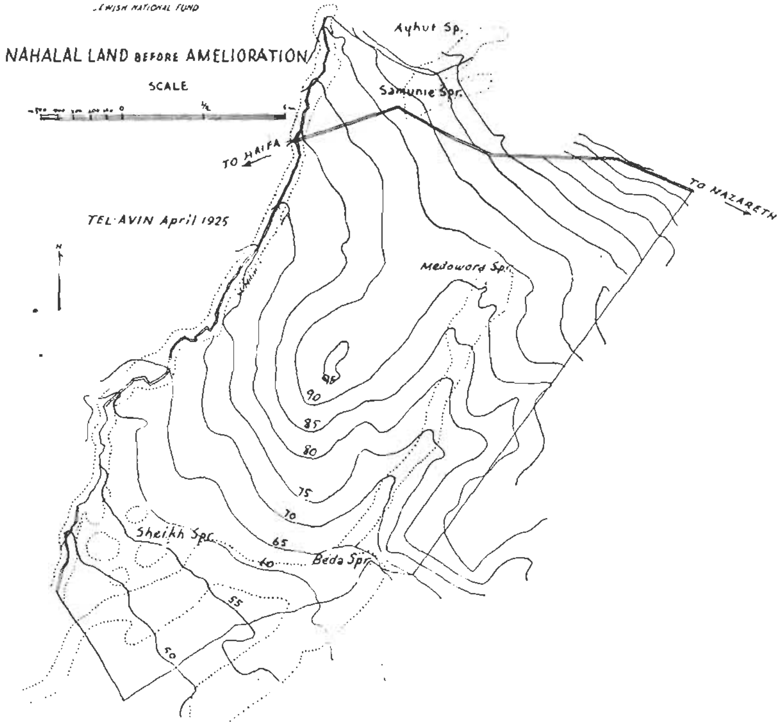
FIG. 21.—Jaloud River—Nuris

LOWER GALILEE

Permanent work in Lower Galilee has been carried out chiefly by the Malaria Research Unit, in co-operation with the villages. In Meskha, a number of

springs were drained and a dam constructed in the Wadi to impound the water. In Yabniel, five small but important marsh areas, caused by springs, were drained by the Malaria Research Unit. Similar work has been done in Menahemia and in Bethania. An important piece of work, also carried out by the Malaria Research Unit, was the regulation of the irrigation system of Bethania and Abedia, and of the two water mills on the Jordan by the installation of

MAP XII



NAHALAL LAND BEFORE AMELIORATION

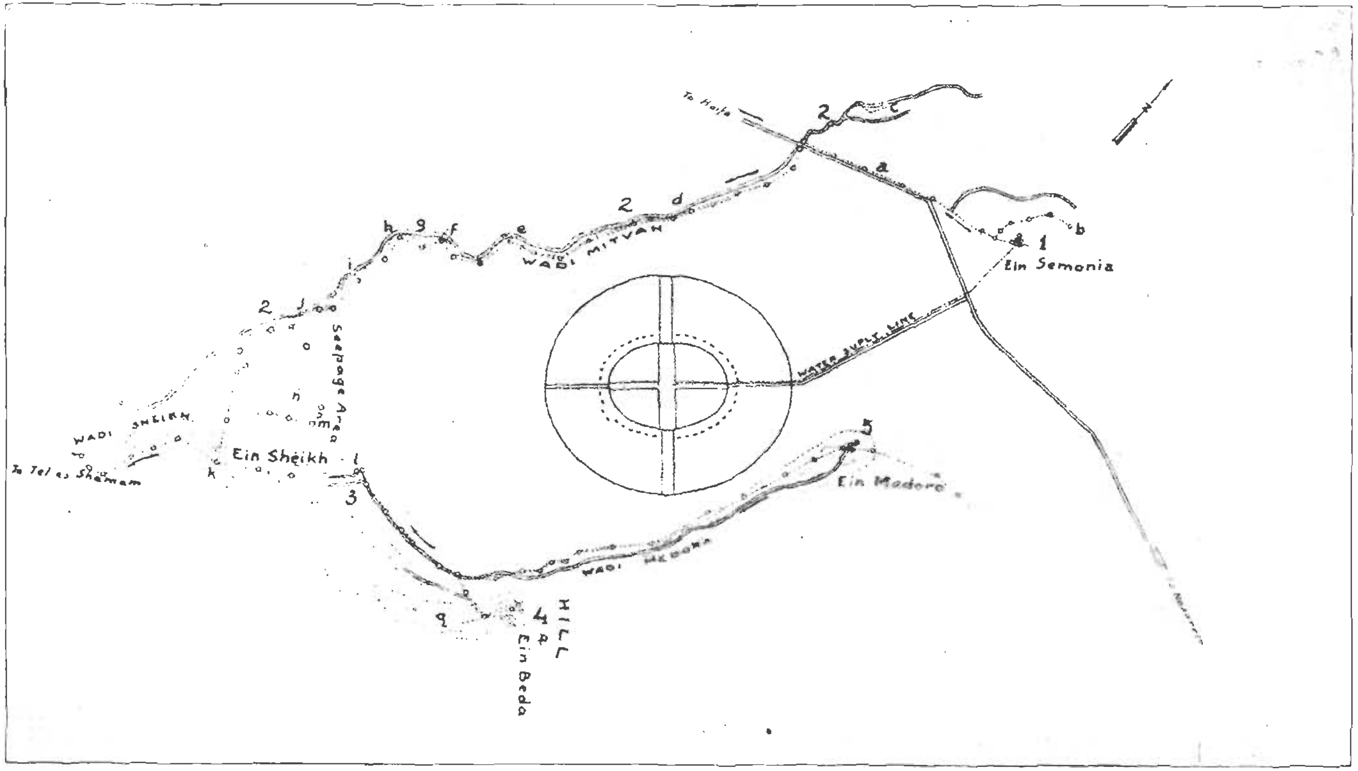
sluice gates. Both the irrigation and mill canals were responsible for extensive breeding-areas caused by seepage from their walls.

METHODS OF DRAINAGE

In general, five different methods of drainage have been used here: (1) subsoil tile drain; (2) open canals to lower the water table and lead off excess flow; (3) impounding and alternation of flow; (4) flooding with sea water; and (5) regulation of stream beds.

The drainage works carried out by the Jewish National Fund and the American Zion Commonwealth in the Valley of Esdraelon were principally of the

MAP XIII



Nahalal Land, Drained

first type. Here the marshes were caused chiefly by overflowing spring and seepage areas which did not have a well-regulated bed. The basis of procedure consisted of interception of the springs by means of canals lined with loose stone, porous tile, or concrete pipes. The collected water was carried off either in a concrete lined canal or in a subsoil pipe line.

In the work done by the Pica, the method of drainage used consisted almost entirely of open channels. The marshes dealt with were of the coastal type, large flooded areas the outlets of which were blocked. It was thought that open canals would lead off storm as well as ground water and gradually lower the water table.

Fig. 22.—A herd of buffaloes in the Kabbara Swamp

It is of interest to compare the results of these two methods. The initial cost of subsoil drains is about 50 per cent higher than open canals. However, in canals carrying only a small amount of water, the growth of weeds in this subtropical climate is so rapid that the maintenance cost becomes prohibitive. As a result of its experience during the last two years, the Pica has decided to put in subsoil drains in canals carrying only a sluggish stream.

Earth canals, on the contrary, have proved entirely satisfactory under the local soil conditions if the volume of water is large and the flow good. Under such circumstances, concrete canals may be more durable, but the difference in initial cost is so great that it seems unwarranted. Concrete canals are necessary only in places where the flow is very sluggish as a result of lack of sufficient fall.

Flooding with sea water has given excellent results. The outstanding operation of this type is the elimination of an extensive coastal marsh at Athlit by

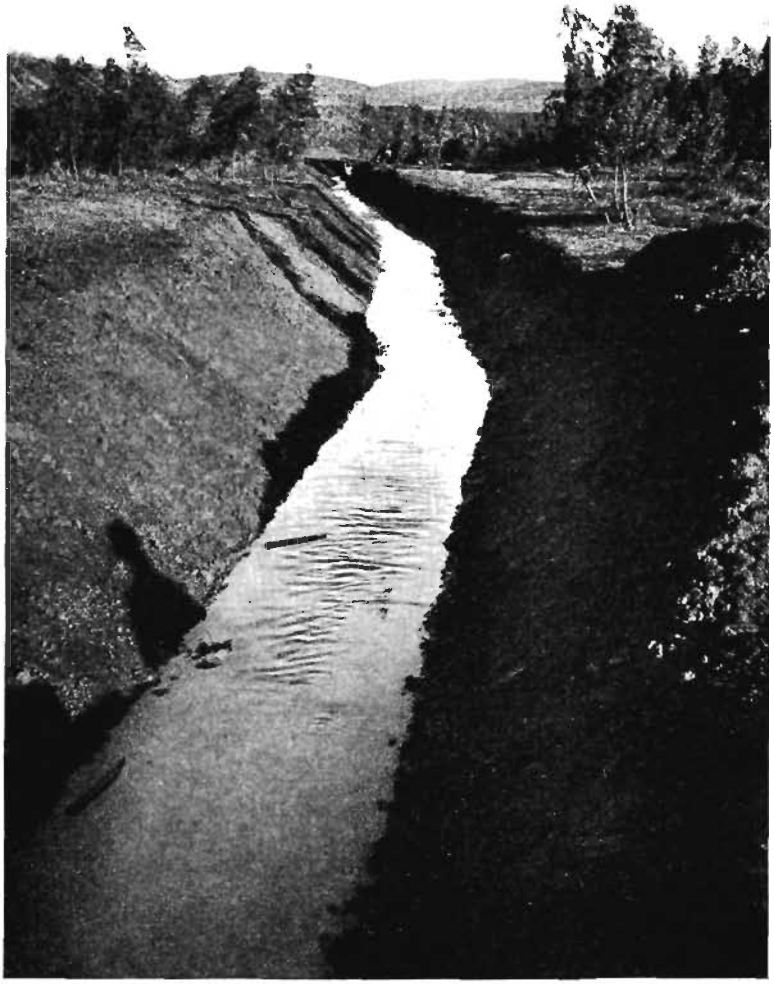


FIG. 23.—Bed of Kishon after regulation

the Palestine Salt Company, which will be described in detail later. In the Kishon River, the sea water backs up for a distance of about 8 kilometers, and in that portion of the stream no anopheles-breeding has been found. This fact

has been utilized in the schemes for draining Wadi Malik and the Fuara. The stagnant water breeder *A. elutus* finds a salinity of 1 per cent unsuitable for its development, while *M. multicolor*, though preferring saline water, is not found in these places. This method offers a simple solution for the outlets of the sluggish streams along the coast if the mouth can be kept open so as to allow a free admixture of sea water in that portion of the stream where the bed is below sea-level.

Impounding and alternation of flow have been used largely by the Malaria Research Unit in treating small streams. It has also been used by the Jewish National Fund at Ein Sakhne. In places suitable for such treatment, it is a cheap and effective measure. Experience has shown that two precautions are required. The basin must not become filled up by rocks washed down by unusually heavy rains. The dam must be sufficiently strong to withstand their onslaught. With these contingencies provided for, the method is extremely useful.

The regulation of stream beds is useful in Palestine. Most of the coastal streams have eroded beds as a result of years of action of the rains in an ungraded stream. The pools thus formed constitute a serious source of malaria. The first experiment was made in Wadi Abulejja with such satisfactory results that the method was employed in Wadis Khudeireh, Ishkar, and Adas, and is now being carried out on a large scale in the Kishon. The first four have now been functioning satisfactorily for from two to four years; it remains to be seen whether the work in the Kishon will withstand the erosive action of the heavy storm flow. Maintenance is required but on the whole not more than for tile drains. The first year the maintenance cost is about 10 per cent of the initial cost, while in subsequent years, as the newly dug beds are stabilized, the cost of repair grows less. This method is particularly effective in hard soils.

1. SUBSOIL TILE DRAINAGE

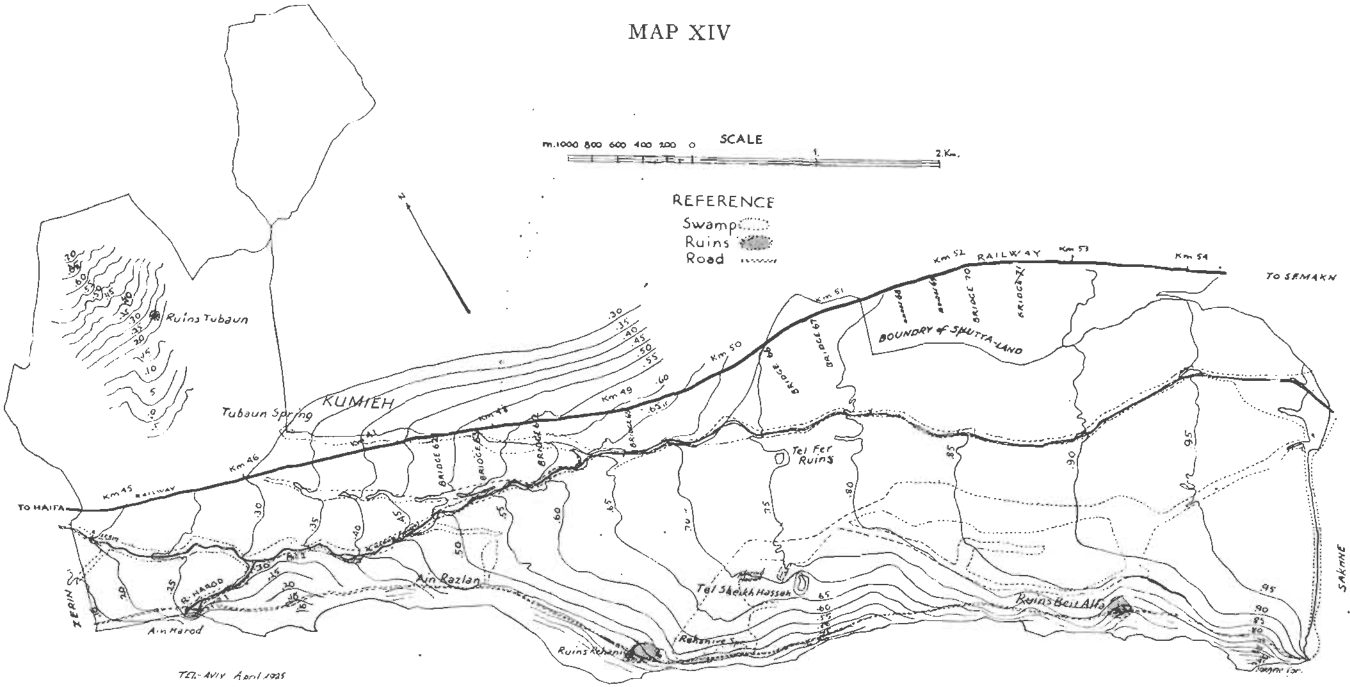
Drainage of the Nuris and Nahalal lands.—The Nuris block comprises some 3,500 hectares of land. The soil is composed of a hard impervious clay. The entire area was extremely malarious and only sparsely inhabited.

The causes of the swamps were threefold. There were a large number of springs without proper drains. In addition to this, there were numerous irrigation ditches. Several water mills on the Jaloud River with their leaky mill runs added to the extent of the marshes.

The whole scheme was developed with the Jaloud River as the central drainage canal. This stream had a well eroded bed along its entire length except at one point for a distance of about 900 meters. It also had a sharp fall and consequently a strong current of water.

The drainage consisted of underground porous tile. The tile was laid on the bed of the canal, at an average depth of 80 to 100 cm. below the surface. The joints were wrapped in tar paper and the tile covered with the excavated material. Both the depth and tar paper were used as protection against clogging by

MAP XIV



NURIS LAND BEFORE AMELIORATION

en growing roots. The experience of the Malaria [illegible]

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FIG. 24.—Subsoil tile drain

deep growing roots. The experience of the Malaria Research Unit has been that it is better where the gravel is available close at hand to lay the tile on about 10 cm. and cover them with from 10 to 20 cm. of gravel before covering with the excavated material. In pipe so laid, the clogging has been negligible,

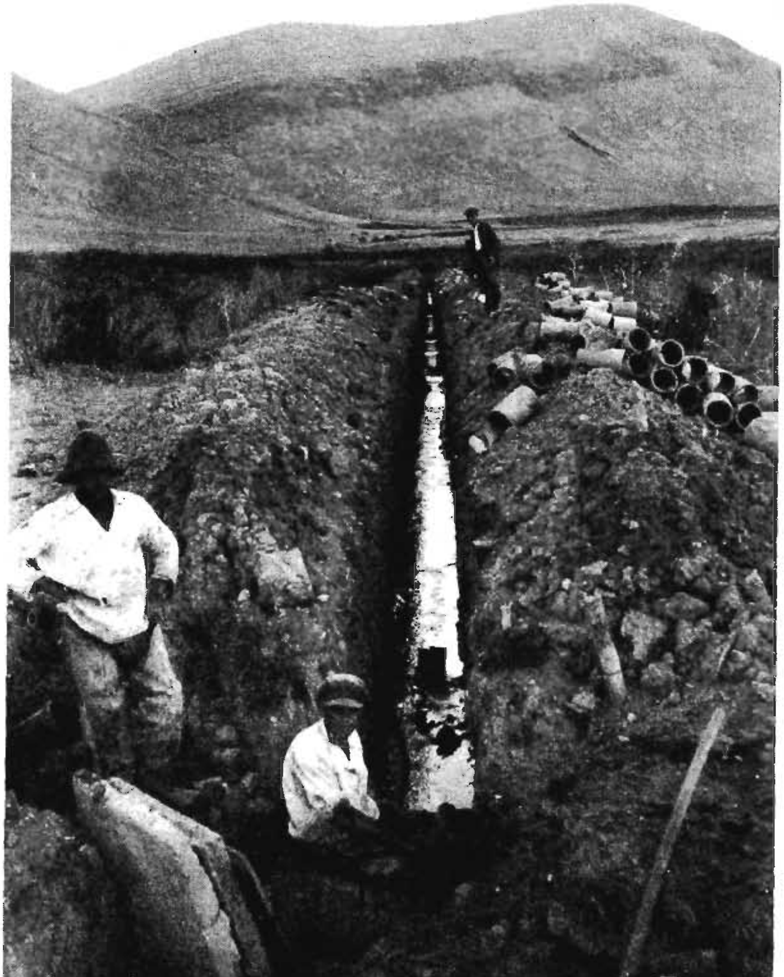
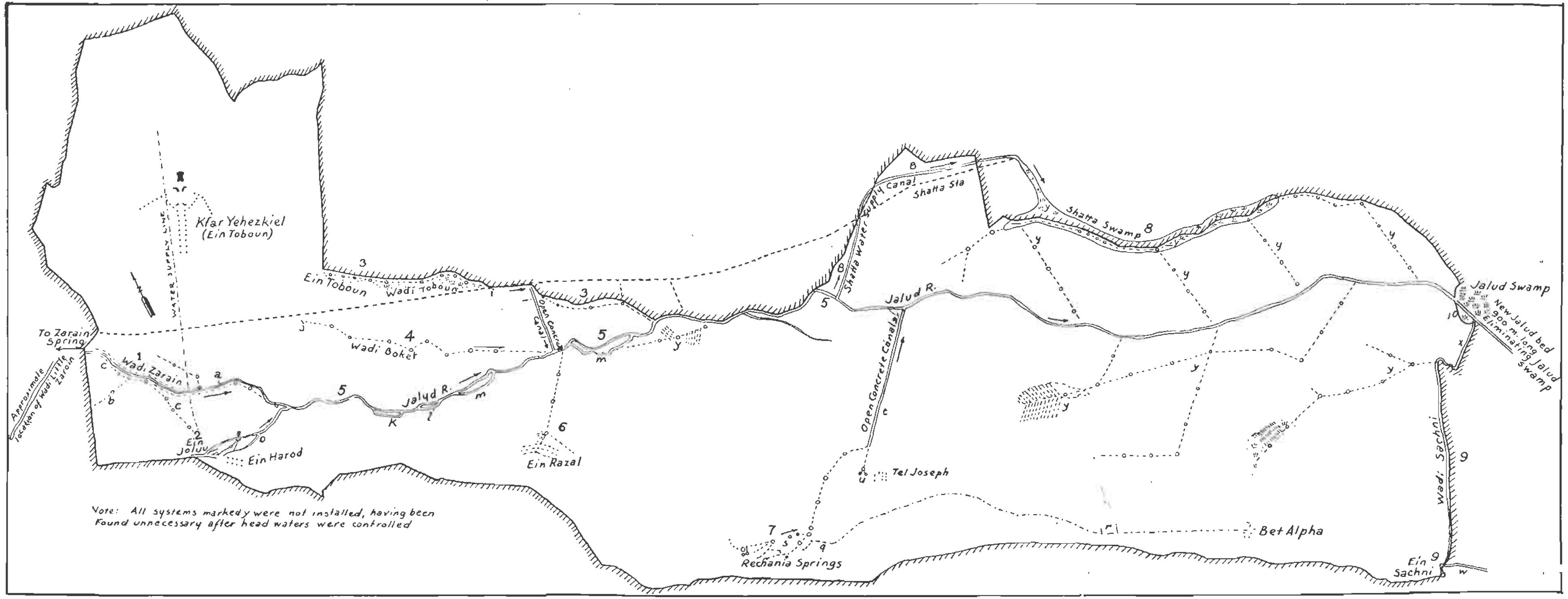


FIG. 24.—Subsoil tile drain

MAP XV



NURIS LAND, SHOWING PLAN OF DRAINAGE AND RESULTS

while in the Nahalal and Nuris drainage clogging is a periodic occurrence. On the whole, the maintenance after the first year has been between 1 and 2 per cent of the cost.

The details of the drainage are shown in Maps XIII and XV. A few words of explanation may, however, be helpful.

The Jaloud springs come to the surface at the foot of Mount Gilboa. To intercept these springs a gallery was built 80 meters long and 80 by 100 cm. in cross-section. The gallery was lined with loose stone and covered with a reinforced concrete roof. The water from this gallery is directed by an open canal in rock to the Jaloud river.

The other springs were collected individually by a herringbone arrangement of clay tile into a central subsoil canal, which conducted the water to the Jaloud.

At Ein Sakhneh, the method of alternation was used and will be described under that head.

Drainage of this type, with the standard cost of labor and laid-in gravel, costs between 25 and 30 P.T. per running meter. The cost varies with the ease with which gravel is obtained. The cost of labor is about 10 P.T. per running meter, the other 15 to 20 P.T. covering the cost of materials and transport. The Jewish National Fund drainage costs more because of the higher wages paid by this institution.

The same general method was followed in the Nahalal and Rub el Nasra drainage.

2. OPEN CANAL DRAINAGE

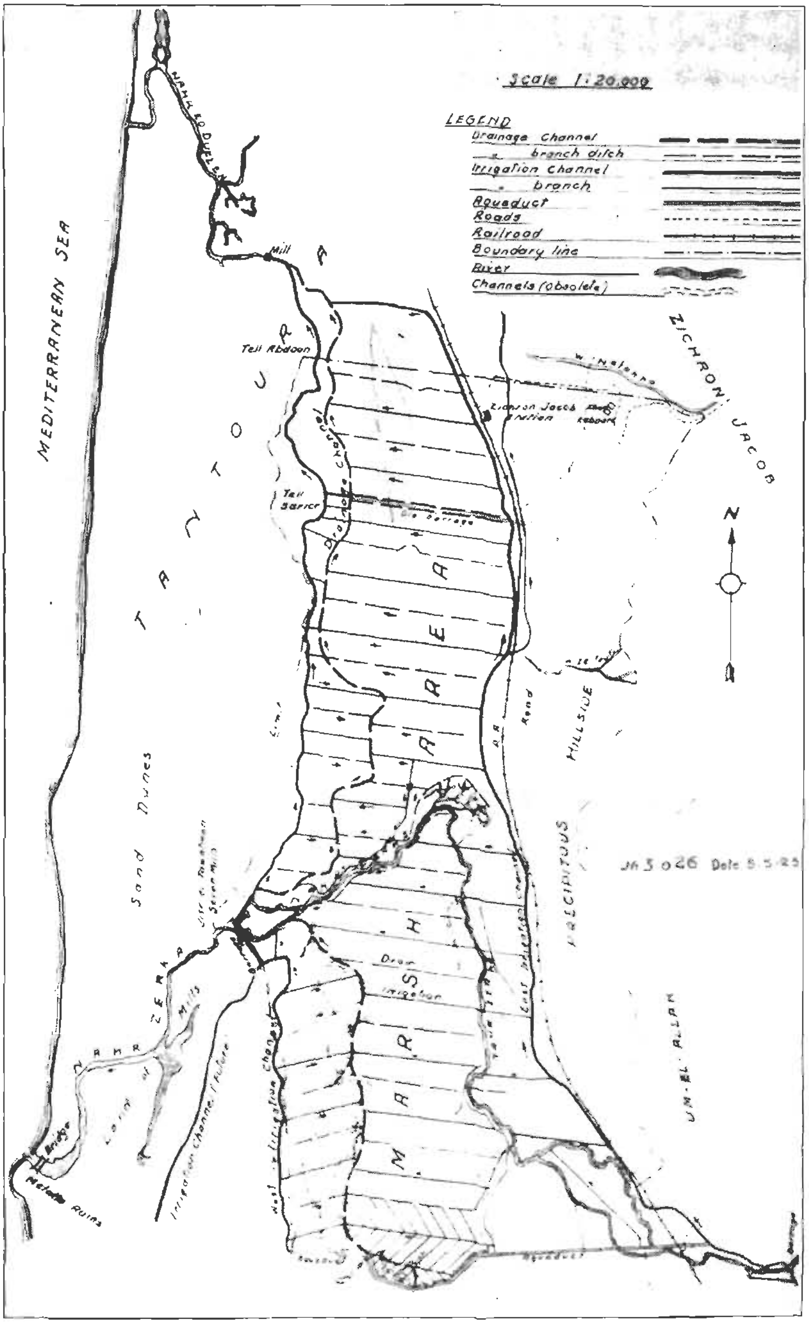
In contrast with this type of drainage is the method employed by the Pica in the reclamation of the Kabbara swamp along the coast. This swamp is a large coastal marsh covering an area of about 6,000 dunams (approximately 1,500 acres) and lies at the beginning of the Samarian Plain along the Haifa-Kantara railroad line between the stations of Zichron Jacob and Benjamina. It was granted by the Palestine government as a concession to the Pica for a period of ninety-nine years on condition that the marsh area be drained.

The swamp is due to various causes: partly to the overflowing of two meandering streams, the Zerka River and Wadi Zurghaniyeh, incapable of holding a large volume of water; partly to the existence of a large number of unregulated springs; and to a considerable extent to the damming of these streams at Jissr el Tawaheen for the operation of a number of mills (see Map XVI). The marshes lie at a considerable elevation above sea-level, but the outlet of the water was effectively dammed.

The scheme for dealing with the Kabbara marshes may be subdivided into two parts: (1) the drainage work as such, and (2) the irrigation project.

a) Under drainage work falls the regulation of Wadi Zurghaniyeh, the lowering of the general water table of the swamp, and the regulation of numerous small springs and seepage areas.

MAP XVI



Kabbara Swamp and Plan of Drainage

The first two items are taken care of by the north and south main drainage canals and their various branch canals shown by dotted lines. The south drainage canal has provided a new bed for Wadi Zurghaniyeh; it eliminates all the

FIG. 25.—Excavation in Kabbara

FIG. 26.—Main drainage canal, Kabbara

bends of the natural wadi bed and at the same time lowers the level of the stream. The lowering of the stream level also of necessity eliminated the mills, which depended for their operation on the raising of the level of both the Zerka and the Zurghaniyeh. An outlet for the new canal was made by clearing out one of the arches of the ancient Jissr (bridge) el Tawaheen and releasing the impounded water. The south drainage canal (Wadi Zurghaniyeh) thus empties into the Zerka on the west instead of the east side of the bridge.

The north drainage canal runs through the center of a low-lying area between the Zerka and the Dufleh rivers and drains into the latter. Its purpose is to lower (with the help of numerous branches) the water table in this area and thereby eliminate the marshes and make the land fit for agricultural purposes.

A second function of both the north and south drainage canals will be to receive the large volume of storm water and the run-off from the irrigation system.

In the Zerka itself no work has been done aside from lowering the general water level by removing the obstruction at the mills. It remains to be seen after the irrigation system is put into operation just how much water will remain in the Zerka and what regulation, if any, will be necessary.

The small springs and seepage areas along the banks of the Zerka are being taken care of by open intercepting canals on either side of the stream. It is doubtful whether these canals will eliminate all the springs. These will only be dealt with when the main project is completed.

The entire drainage consists of open canals. This form of drainage is undoubtedly cheaper than subsoil tile drains. The cost of maintenance has, however, proved so high in the lateral canals carrying small amounts of water that the Pica has decided to lay them with tile and cover them. The exact cost of maintenance has not been made known, but it was evidently prohibitive.

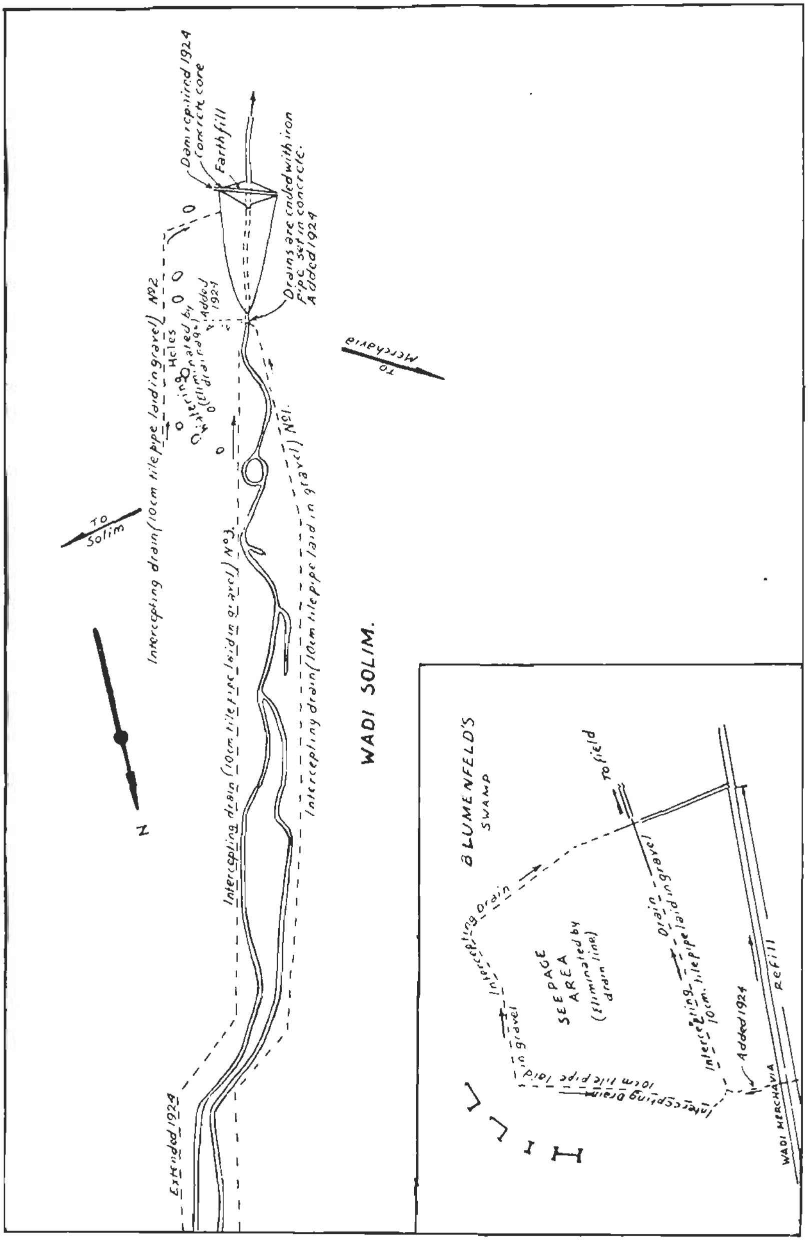
Our experience has shown that, as in other subtropical countries, unless canals carry a large rapid stream of water, they become overgrown with vegetation so quickly that maintenance becomes prohibitive. Open canals have been used effectively for the drainage of the Beisan marshes because of the large volume of water and rapid flow.

3. IMPOUNDING AND ALTERNATION

Wadi Solim.—This is typical of a class of wadis in the foothills of the country. The water is derived either from springs or seepage areas. The water in this wadi is derived from seepage from both banks for a distance of 300 meters. The volume of water is too small to form a stream, but it is large enough to wet the bed for a distance of 1 to 2 kilometers. The cattle do the rest. A serious marsh about 20 dunams in extent was thus formed at a point midway between two villages and only a kilometer or so from each.

The wadi was treated by intercepting canals dug along the top of each bank. The canals were laid with 10-centimeter clay tile pipes in a bed of gravel.

MAP XVII



Wadi Solim, Showing Plan of Drainage and Impounding of Stream

Just beyond the outlet of the drains a dam was built to impound the water. At first an earth dam with a simple concrete core was built. This stood up well for three years but was destroyed by the flood rains during the winter of 1926, and was replaced by one made of reinforced concrete.

The impounded water is being used for watering the cattle. At intervals the water is released through a 6-inch iron pipe set in the dam, and the basin dried.

The dam serves a double purpose. It saves the cost of running a subsoil drain for 2 or more kilometers. Moreover, it provides a watering basin for the cattle and serves to eliminate the numerous watering holes.

A similar plan was carried out at Melat Swamp.

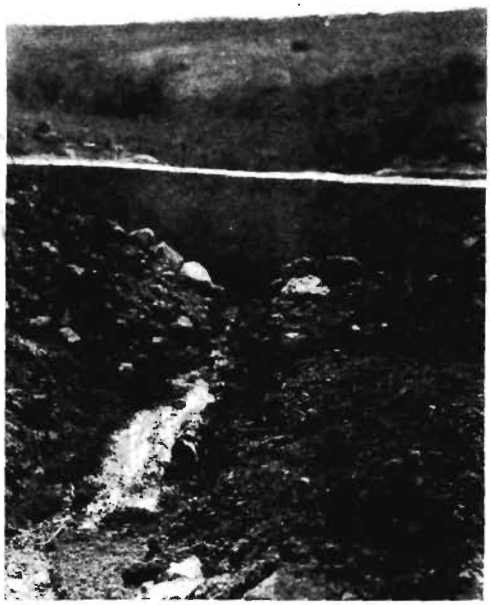


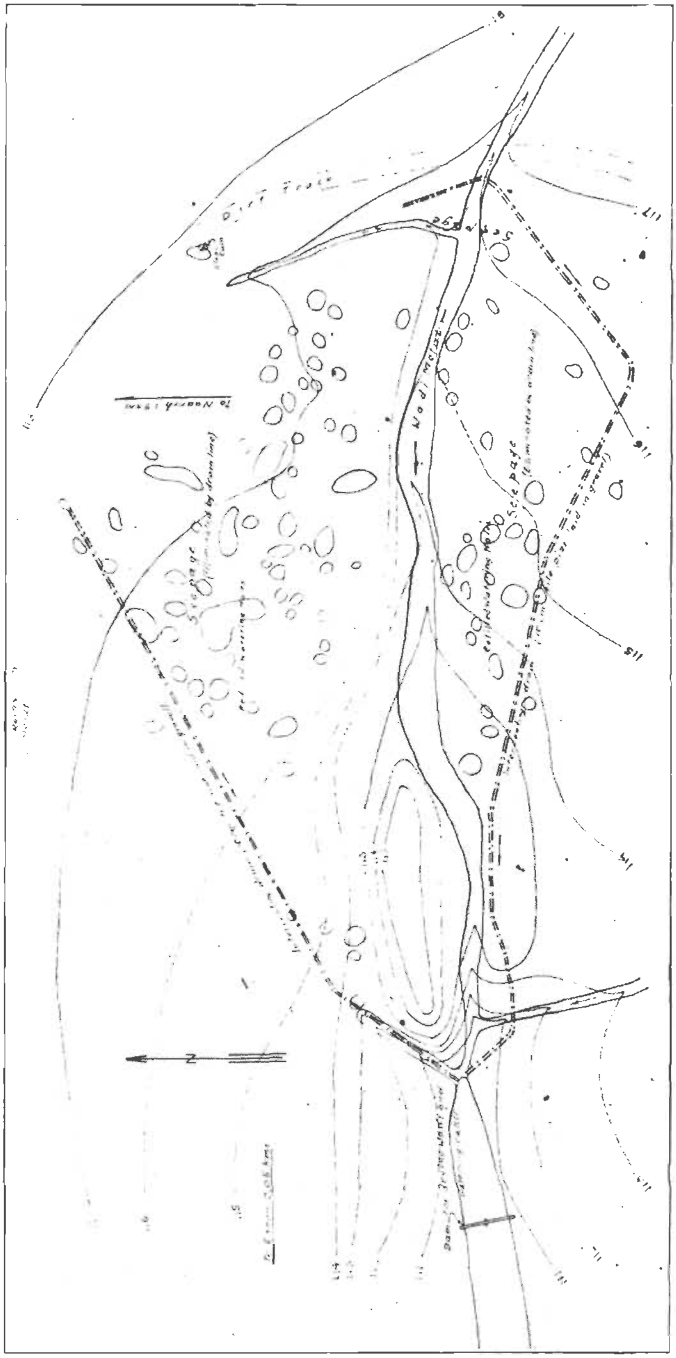
FIG. 27.—Concrete dam for impounding water in a foothill wadi.

Melat Swamp.—Location: The swamp was located on the west side of the Jaffa-Jerusalem railway line between the stations of Naaneh and Vale of Sorek. Its northern limits lay 1.9 kilometers south of the village of Naaneh and its western limits 2.05 kilometers east of the village of Ekron (see Map XVIII).

Description and history: The swamp extended for a distance of 300 meters on either side of Wadi Melat. It consisted of ninety-seven pools of standing water with marsh land between the pools in the lower ground near the wadi. The pools were mostly artificial watering holes dug by the peasants of the neighboring villages for their sheep and cattle. The large number of pools is due perhaps to the fact that as a pool became overgrown with swamp grass it was found easier to dig a new one in the soft boggy ground than to clean the old ones.

The actual causes of the swamp are the seepage outcrops from the bases of the two hills between which the wadi flows at this point. The most of the seepage is from the base of the larger hill on the north side of the wadi, on the top of which are still to be seen the ruins of the ancient village of Melat. These ruins bear vivid testimony to the prevalence of malaria and the extent to which its forces may operate. The descendants of the survivors of Melat live today in the village of Naaneh.

MAP XVIII



MELAT SWAMP

Method of eradication: Drainage was accomplished by intercepting the seepage with canals cut at the base of the hills on both sides of the wadi. Ten-

FIG. 28.—Ein Sakhneh Marsh

centimeter tiles with open joints were laid on the bottom of these canals and were surrounded with about 30 cm. of gravel. The rest of the canal was refilled with the excavated material.

The drains lowered the water table in the swamp sufficiently to eliminate all the seepage existing between the watering holes. A corresponding drop also occurred in the water in the pools, but not sufficient to dry them completely, and the majority had to be filled. For this purpose the surplus earth from the canals and sand from a nearby deposit were used.

About 40 meters below the outlets of the drains a concrete dam, with a 15-centimeter outlet at the bottom, was constructed across the bed of the wadi with sufficient height to store a minimum of three days' flow of water. The flow of water varies according to the season: the maximum flow occurs during and immediately after the rainy season, that is, winter and spring, and gradually diminishes until a minimum is reached in October, at the end of the dry season.

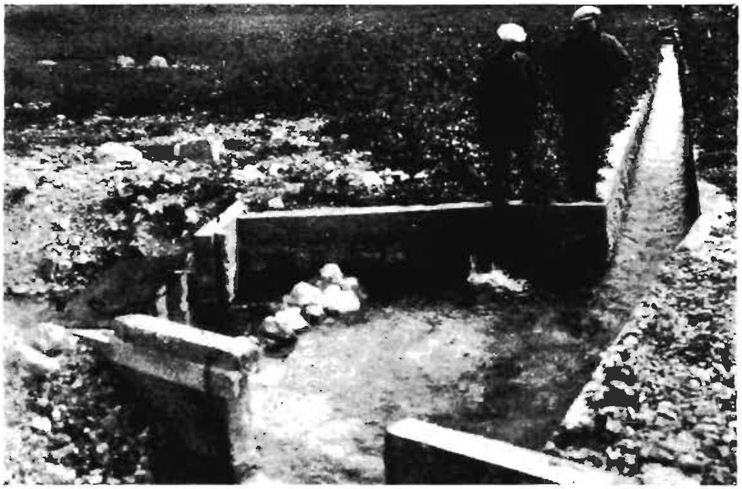


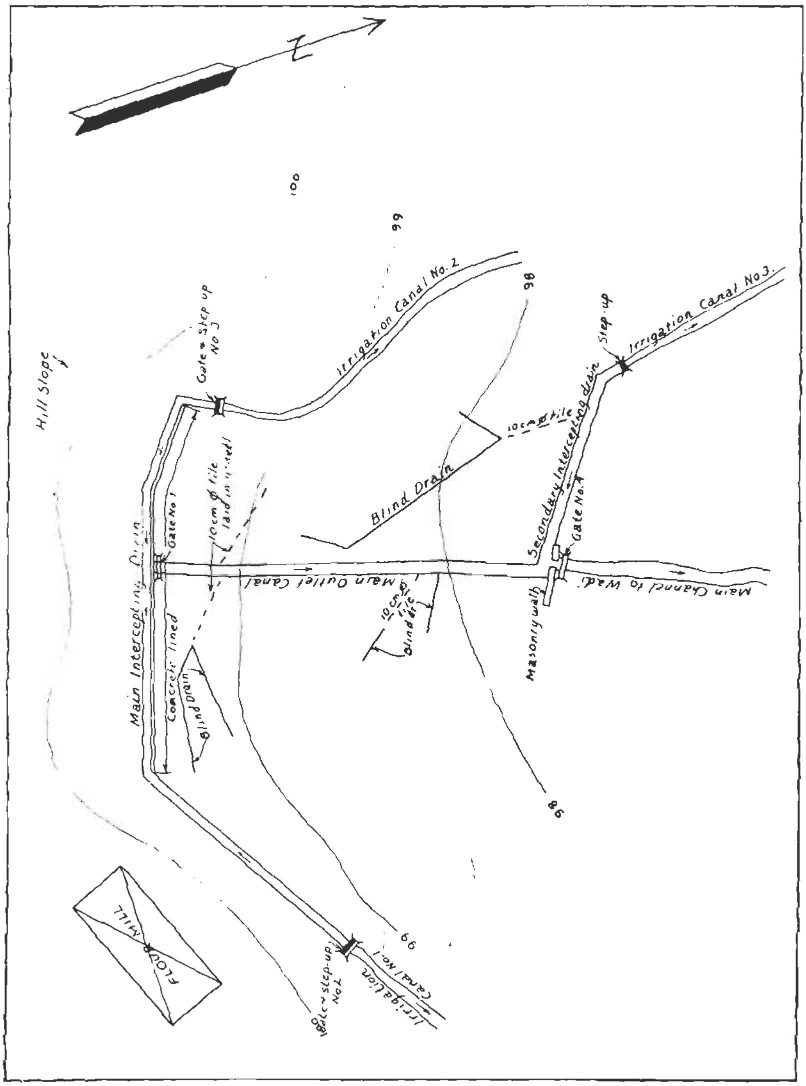
FIG. 29.—Weir regulating flow of waters of Ein Sakhneh; N, north channel, E, east channel

The purpose of this dam is twofold. First, the stored water replaces the old overgrown watering holes as a source of drinking water for the cattle in the neighborhood and removes the need for the excavation of new holes. Second, the dam accomplishes the important purpose of allowing the wadi below the drains to dry during the three or more days when the outlet is closed and the water is being stored. Complete control of the entire wadi is thus obtained.

Of particular interest is the method used in treating Sakhne springs. This was a voluminous spring without a stream bed, giving 180 liters a second. The waters spread out on the depression near the spring and ultimately divided, one portion meandering north to the Jaloud and the other east to the Asi. The springs were collected in a channel and carried in an open stone canal to a weir

having two gates: one on the east, and the other on the north side. From these gates irrigation canals were dug, one north to the Jaloud, the other east to the

MAP XIX



EIN MAVITEH—METHOD OF DRAINING

Asi. Every five days the water is diverted from one canal to the other. By this relatively simple and cheap procedure an extensive marsh was eliminated and controlled irrigation instituted (see Figs. 28 and 29).

This method has many applications in Palestine and makes possible considerable saving in the cost of drainage. The same principle has been used in treating Ein Mayiteh.

Ein Mayiteh.—Ein Mayiteh is a seepage outcrop at the foot of the hill on which the village Zarain is located. The water issues from a few points in the form of springs, and in addition there is seepage along a considerable area where the gravelly water-bearing stratum is exposed. Before the drainage work was done, the water spread out over an area about 100 by 250 meters, creating a bad gravelly marsh, and thence ran in a more or less confined irregular wadi toward the Jaloud River.

At the upper part of the seepage area, irrigation canals were led off to the east and west.

The plan of drainage consisted in an intercepting canal, a few subsidiary tile drains, and gates for regulating the irrigation.

The main interceptor is an open canal running from east to west and cutting off most of the seepage. At either end of this canal are 10-centimeter step-ups to irrigation canals. Simple iron gates at these points permit the closing of the irrigation.

At the center of the main interceptor there is an opening leading to the main drain canal. Here there is a large gate. When this gate is closed, the water in the interceptor rises and flows into the irrigation canals. When the gate is open, the water flows into the wadi and the irrigation canals are dried.

Fifty meters below the main interceptor, there is a secondary interceptor which deflects the water into a third irrigation canal.

The details are shown clearly in the accompanying sketch map. The whole and dotted lines indicate blind and subsoil tile drains, respectively.

4. FLOODING WITH SEA WATER

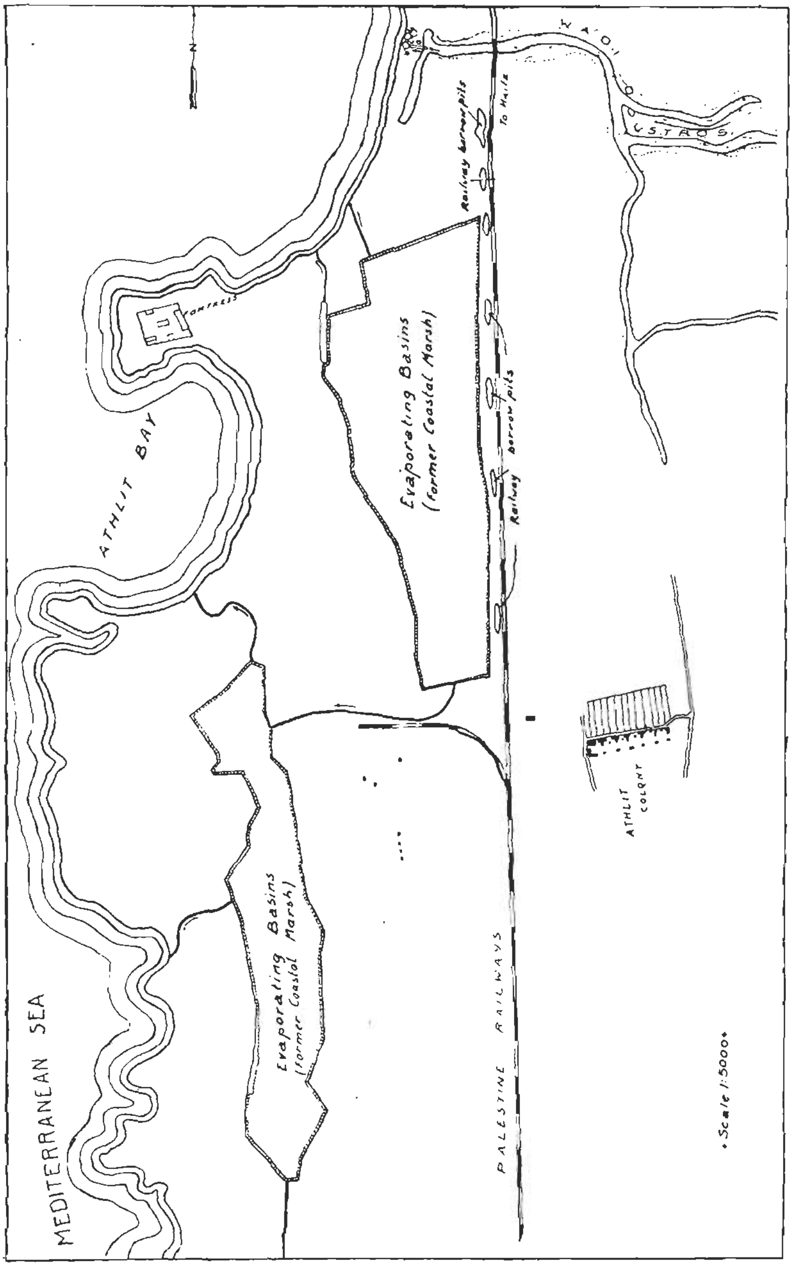
The work of Athlit is the outstanding example of the application of this method to the elimination of anopheline breeding-marshes. This work, carried out by the Palestine Salt Company, was incidental to the building of salt pans.

The marsh of Athlit was a typical coastal swamp. It consisted of a series of land-locked basins, the outlets of which were blocked by a sandstone ridge running parallel to the sea.

The Palestine Salt Company used these basins as salt pans. The swamps were partly drained by means of a canal leading the water to the sea. The vegetation was then cleared and the marshy beds enclosed in dikes of wood and earth. These areas became the sedimenting and evaporating basins. The basins are filled with sea water pumped from the Mediterranean. The former marshes are thus constantly covered with a concentrated salt solution. The plan is shown in the accompanying map.

This principle is also being applied in the drainage of some of the streams in the Haifa-Acre Plain. It is a simple, inexpensive method wherever it can be employed.

MAP XX



ATHLIT—SALT BASINS

5. REGULATION OF STREAM BEDS

Wadi Abulejja and Wadi Khudeirah.—Location: Wadi Abulejja is in Judea on the south side of the Auja (Yarkon) River. Its upper part is about 1 kilometer from the village of Fejja, while Mahneh Yehuda, Ein Ganim, and Petah Tikvah lie from 2 to 2.5 kilometers from the wadi.

Wadi Khudeirah flows almost due west across the northern part of the Plain of Samaria and enters the sea just north of the village of Hedera, which is about 1.5 kilometers from it at the closest point. Only that part of the wadi affecting Hedera and Nahliel (2.5 kilometers away at the farthest point) was taken care of.

FIG. 30.—Wadi Khudeireh after regulation.

Description: The Palestinian wadi when it emerges from the hills into the plain presents a most difficult problem in malaria control. The summer appearance of such a wadi is that of a very tortuous stream bed, cut sharply and deeply below the level of the plain, with no flowing stream, but an intermittent succession of dry places and pools of stagnant water. These pools are often as much as 3 meters deep, and vary from 5 to 15 meters in width, and from a few meters to 300 or even 400 meters in length. Their banks are usually densely overgrown with reeds and thorn shrubs, and the pools proper with algae, ranunculi, and other types of aquatic vegetation. To keep pools of this type free of vegetation in a subtropical country is difficult. It requires a considerable amount of labor and constant attention throughout the spring, summer, and fall months.

In the winter during heavy rain storms, the same wadi is a racing torrent. Occasionally, there is so much water that it leaps over the banks of the wadi and floods the adjacent fields. This only lasts for a short time, however, and very soon after the storm the water in the wadi subsides almost to its summer condition, excepting for a small stream which persists until spring.

Method of eradication: The plan of work in the two wadis was different. In Wadi Abulejja, apart from grading, the wadi was straightened and shortened as much as possible by cutting an entirely new bed in three places (see Map XXI). The entrance to the eliminated portions of the old wadi bed were blocked with

dams of timber and earth so that the winter storm water would not enter them and re-erode the filled pools.

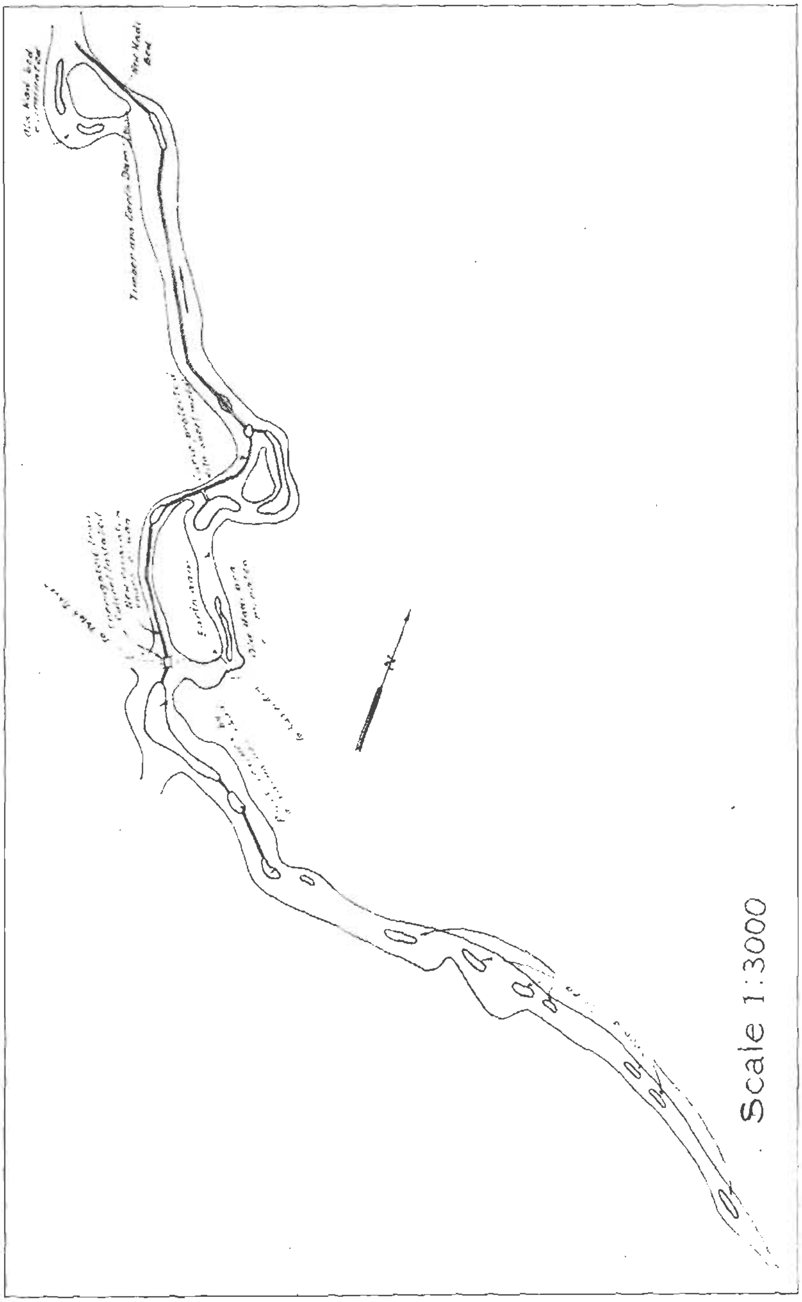
In the upper part of the wadi, standing water was eliminated entirely by filling. This method was used because the presence of an unlimited supply of large gravel for top fill material made it more economical than grading by excavation.

FIG. 31.—Wadi Ishkar before regulation, Petah Tikweh area

A bend in the newly excavated wadi was protected against washouts by lining with heavy (4 mm.) zinc sheets. These sheets are attached to heavy logs driven into the banks of the cut.

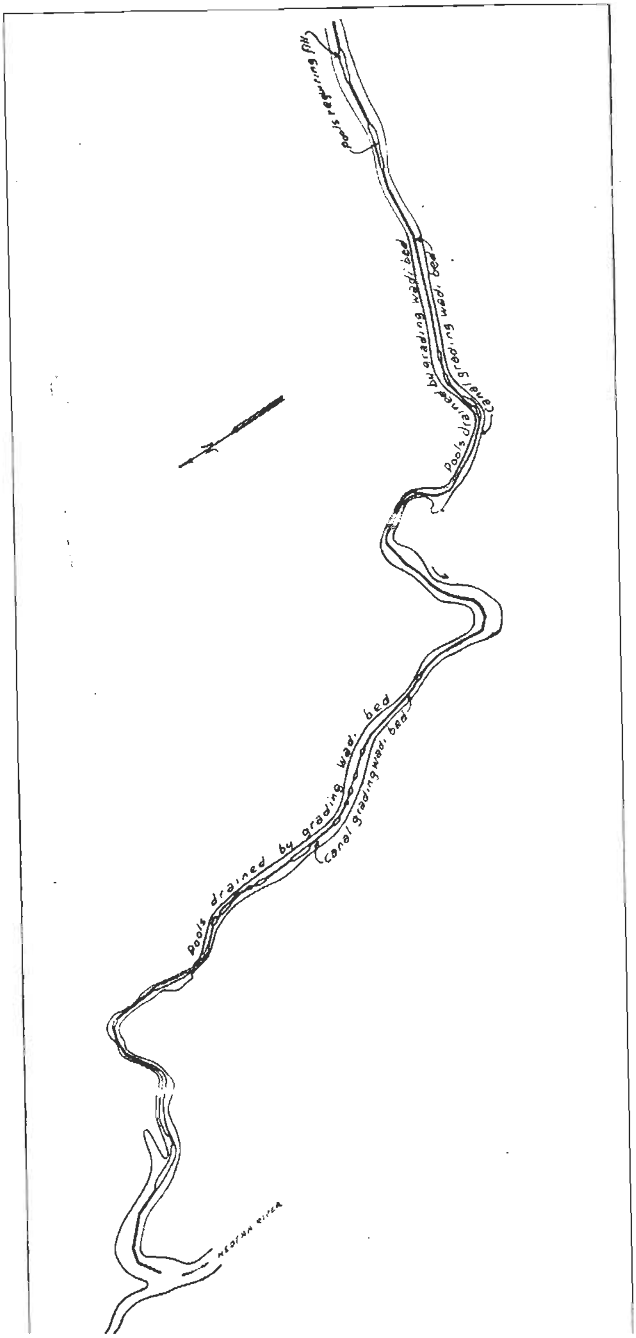
In Wadi Khudeirah only grading was done, almost entirely by cutting, because of the absence of proper fill material. The bed of the stream is so deep that no attempt was made at straightening; the canals all follow the old course. The water was run off into the river Khudeirah (see Map XXII).

MAP XXI



WADI ABULEJJA

MAP XXII



WADI KHUDEIREB

These two wadis have now been carefully watched for three winters. The heavy storm flow has caused some damage. But until the present time the work has proved entirely successful. Wadi Abulejja now dries completely after the rains are over, usually in April, and maintenance cost has been practically nil.

FIG. 32.—Regulating a winter wadi, Wadi Ishkar

Wadi Khudeirah does not dry until July, and in some places the banks are weakened by seepage and require annual repairs. The cost of maintenance has not, however, exceeded £20 for 3 kilometers of wadi, or 10 per cent of the initial cost. With proper maintenance and the annual repair of the small amount of damage done, the method is most satisfactory for this class of stream bed.

The Jewish National Fund is now applying this method in the regulation of 25 kilometers of the Kishon.

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